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DESIGN, SIMULATED OPERATION, AND EVALUATION OF A SHORT-PERIOD SEISMIC DISCRIMINATION PROCESSOR IN THE CONTEXT OF A WORLD-WIDE SEISMIC SURVEILLANCE SYSTEM

1

TECHNICAL REPORT NO. 9
VELA NETWORK EVALUATION AND AUTOMATIC PROCESSING RESEARCH

Prepared by
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Prepared for

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Alexandria, Virginia 22314

Sponsored by

ADVANCED RESEARCH PROJECTS AGENCY
Nuclear Monitoring Research Office
ARPA Program Code No. 6F10
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29 October 1976

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A brief summary of a series of system studies describes the data flow, file structures, and data processing required to operate a world-wide seismic surveillance network. One of the design problems in developing a surveillance mode of operation is to provide the seismic analyst-computer interaction needed to efficiently perform discrimination processing to effectively classify events as earthquakes or explosions. Efficiency is required to keep up with

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To partially fulfill these requirements, a special purpose Interactive Seismic Processing Module was developed on a PDP-15 minicomputer for Short-Period Earthquake/Explosion Discrimination (SPEED). This processing module was imbedded in a simulated special purpose seismic operating system, Interactive Seismic Processing System (ISPS) developed by Ringdal and Shaub. All of the capabilities for waveform processing using SPEED were described and demonstrated by processing a seismic event and displaying the results of each stage of processing. Support programs were developed to use an IBM 360/44 computer to reduce all of the station component seismograms to a single representative event waveform. An option is provided for inputting into SPEED the single representative event waveform either corrected for or uncorrected for system response. The examples analyzed were corrected to broadband ground displacement between 0.25 and 5.0 Hz.

The SPEED processing module as presently configured can be programmed to perform any one of many discrimination procedures by a prescribed sequence of button pushing. To obtain baseline performance data, one very simple and reproducible discrimination processing procedure was prescribed. A data base of 35 events, including 20 earthquakes and 15 presumed explosions in the magnitude range between 4.4 and 6.1, were run through the SPEED processor. For each event, the discrimination measurements obtained from SPEED were processed by multivariate discrimination analysis of frequency dependent magnitude measurements to derive a two-component discriminant output. One component was optimized to discriminate central Asian presumed explosions. The other component was optimized to discriminate western United States presumed explosions. The performance results obtained by analyzing the length of the two-component discriminant vectors were to clearly separate earthquakes from presumed explosion events from the two regions. Assuming normal statistics, it is expected that 90 percent of the presumed explosions can be detected with a probability of false positive identification of 4×10^{-3}. Two outliers were obtained; one from each presumed explosion region. This indicates the need for more discriminant components in the measured discriminant vector, and possibly more components in the resultant discriminant space needed to identify all explosions by region or medium type. Before considering use of some of the more advanced capabilities of SPEED, significant improvements over these baseline results should be firmly established.

ABSTRACT

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I gratefully adknowledge J. S. Shaub for his association in planning the implementation of the Interactive Process Module, SPEED, and its imbedding into the higher level Interactive Seismic Processing System (ISPS) developed by F. Ringdal and J. S. Shaub. I received considerable systems programming support from D. A. Eastburn, who performed most of the implementation of SPEED on the PDP-15 computer at the Seismic Data Analysis Center. Suggestions for improvement, made by J. R. Filson (absorption correction) and R. W. Alewine (band-limited echo) and others, are currently being implemented by D. R. Lashmit. Support data preparation programs were programmed by R. L. Whitelaw. The least squares multivariate discrimination analysis described in this report was programmed by A. W. Schmidt.

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SECTION I

OVERVIEW

A. INTRODUCTION

Over the past several years Texas Instruments Incorporated has performed a series of system studies. The first of these defined the surveillance problem and the functions required to perform it. From this it was possible to describe facilities, data flow, file structures, and hardware or software requirements for seismic data processing and communications processing.

A report was written to analyze the most feasible means of utilizing past measurements of seismic events and seismic noise. Past history of the seismic noise and seismic event measurements can be used to improve the front end detection of seismic events and to improve the quality of seismic event waveform estimates, given the location of a newly detected event. Another feasibility report was written to evaluate where automatic data processing can be most effectively used. Possible areas of application are for front-end seismic event detectors, detection association processors, and event waveform retrieval processors. Also considered were the seismic analyst interpretation tasks which need to be supported by interactive graphics processing. This type of information processing was used for waveform alignment, later phase picking, recursive event focal parameter estimates, reduction of many event waveforms to one or several to be used for discrimination processing, and earthquake and explosion discrimination processing.

This report and several preceding reports are part of the present phase of system design studies to develop and evaluate the computer

codes needed to perform surveillance functions. To facilitate rapid development, these are performed in a mode which simulates surveillance mode operation. Interactive graphics programs were developed to perform long-period and short-period seismic event analysis. Automatic programs were developed and tested to perform detection association processing and waveform retrieval.

B. SYSTEMS ANALYSIS OF A WORLD-WIDE SURVEILLANCE ENVIRONMENT

This report continues the series of system studies by Texas Instruments Incorporated to develop feasible and economically viable options of implementing a seismic earthquake and explosion surveillance system. The first of the reports by Sax et al. (1974) scoped the problem of defining and parameterizing a system capable of monitoring world-wide occurrences of earthquakes and explosions. One of the parameters scoped was sensor deployment, ranging from a network of single sensor stations to a network of array stations. Another parameter was the data collection mode. At one extreme, a centralized system forwards all raw seismic data to a central facility. There, the seismic events are detected, classified and documented. At the opposite extreme, to accomplish the same mission a decentralized system forwards only selected data and information. In that case data processing for event detection and waveform retrieval is partitioned between computer processing at remote sites and computer processing at the central facility.

The 1974 system study report was written to provide systems analysis for implementing and operating a seismic surveillance system. The report specified definition of data processing functions, definition of files, allocation of storage, control of access to data and information files by automatic processors or analyst-driven function processors, communications,

and communications control functions. Given this level of function requirement definition, it was possible to specify preliminary designs of facilities, hardware and software modules needed to perform required functions, and of interfaces needed to synchronize performance of the function processes. The function processes were designed to transform on-line files of raw seismic data to event associated data and information. The function processes and file structures were defined with sufficient generality to accommodate ground motion measurements either by a single component sensor, multiple component sensor, multiple sensors distributed as array elements, or complexes of arrays. This generality of software and file structure enables the system to adapt to changes in sensor deployment. For example, single sensor stations could be converted to array stations without interrruption or serious adverse effects on the performance of seismic surveillance.

If the seismic surveillance system is designed to be implemented and operated as an integrated system, the managers of the network could alter the size of arrays or could add or subtract remote stations to meet almost any future anticipated requirement for seismic event detection capability. Top down planning of the design for this kind of flexibility requires in advance detailed quantitative specification of all data processing functions; of the content and size of storage files; of the control needed for sequential access to data files by parallel operating function processes; of the communications capacity requirements; of the system reliability and recovery requirements; and the limit of time delay tolerance allowable before a final seismic event classification is obtained.

One important system design decision is to select either a centralized or decentralized mode of seismic data collection. Given the present state of the art, either type of data collection can meet any reasonable anticipated requirements for the system monitoring world-wide occurrences of earthquakes and explosions. The main impact of this decision is

on the size and capabilities of remote and central facilities to hold, process, and forward data. The decision should therefore be made before firming the design of such facilities. A decentralized data collection system utilizes station disk files and remote station processors to send reduced data and information to a central facility. A centralized system utilizes much simpler direct sensor to satellite data collection links to send all sensor data to a central facility. In both cases it is anticipated that each remote station's raw seismic data will be held for at least six to eight hours pending the data retrieval needed to analyze each seismic event. These event data retrievals are driven by automatic and independently activated station threshold detections. The detections, sent asynchronously as bulletins from the remote stations to a central facility are linked by an automatic station detection association processor to specific seismic events focal parameters, e.g., origin time, location, and depth of earthquake. The detection association processor utilizes detection bulletin information to obtain the location and origin time of the event. It must do this to predict event arrival times at all remote stations. The predicted arrival times should be accurate to within the order of ten to twenty seconds, to assure confident retrieval of two-minute signal centered short-period seismic event waveforms as well as the one-half hour long-period waveforms.

One advantage of a decentralized over centralized data collection is the estimated 15 to 20% lower cost of implementation and 10-year operation. Another advantage is the capability for more responsive computer assisted quality control of sensor operation at remote sites. The quality control, e.g., detection and repair of bad sensors, can be more readily performed by staff personnel with equipment available at the remote station processor facilities.

One advantage of centralized data collection is simultaneous world-wide access to all of the raw sensor data. Because of this access and

the lack of communication delays, higher false alarm waveform retrievals can be tolerated. These would be caused by detectors operated at lower thresholds. This could result in some increased network event detection capability. It is also possible that hardware and software economies of scale can be built into performing all of the station level detection and waveform retrieval by means of simultaneously parallel station detection processing. Recoverability from system overloading,due to abnormal event occurrences such as earthquake swarms, is faster and more certain because of simultaneous access to all of the raw seismic data files. These can be temporarily dumped onto and retrieved from backup tape or disk units. If a satellite data collection system is built, it is expected that considerable excess satellite data communications capacity would be available for use by other agencies on a when-available basis. For example, lower data rate missions, such as collecting earthquake prediction data, can utilize the excess capacity of the satellite seismic data collection system to forward measurements to a central facility. By so sharing the cost of the data collection system, there could result a considerable communications cost savings for participating agencies. A disadvantage of a centralized data collection system is the longer and more critical development path with more technological risks.

However the decision is made between centralized and decentralized data collection, design studies of algorithms required to perform surveillance system's functions can presently be performed. This can be done in a simulation mode prior to finalizing their design. By iterative design and testing, certain critical functions such as detection association processors, event classification processors, and station detection processors can be specified in minute detail. To the extent that detailed specification of function processors are realistic, the code required to perform the functions can be developed free of faults. Finally, top down design of an integrated surveillance system, i.e., facilities, hardware, and software, is feasible after achieving such a level of problem definition.

C. FEASIBILITY ANALYSIS OF PARAMETER UPDATE PROCESSING

To optimize the operation of a network of event detectors, thresholds can be controlled to obtain the highest possible detection capability in areas of surveillance interest. For a network of array stations, performance optimization also involves improving event estimation by correcting for consistent bias in beamforming parameters, i.e., for anomalous transmission time delays, and for anomalous transmission amplitude attenuation factors.

The performance of the network for acquisition of seismic event waveforms depends on the operating characteristics of the station detectors. These flag possible arrivals of events by means of bulletins. Given these bulletins, a detection association processor times and locates the seismic events. At the station level, sensor data is registered and held on disk pending the request of event waveform data. A front end detection process is performed on the newly registered data. The detector searches for indications of new events by detecting large amplitudes on single sensors or on waveform estimates derived from array sensors. The start time of large amplitude excursions provides a first estimate of the event arrival time. To estimate possible event arrivals on arrays, a set of targeted locations are scanned for events originating from the vicinity of one of the targeted locations. Thus array detections yield not only event arrival times but also associated location ellipses. In that case, any point within a large elliptical area centered about the targeted location is a possible location of the detected event. Since large amplitude excursions can occasionally result from ambient seismic noise, thresholds are set high enough to eliminate most large amplitude excursions due to noise. But this is done at the cost of missing smaller events. Each level that a threshold can be set can be characterized by a rate of false alarms due to noise as well as by the probability of missing an event of some specified magnitude and distance. Each threshold level of

a station detector implies a point on the curve of false alarm rate versus probability of missing the targeted signal. This curve is the operating characteristic of the front end detector. It is important to use thresholds to limit the expected number of false alarm bulletins. At the network level, arrival times at four or more stations are needed to time and locate events. This focal estimate is used to drive requests for event waveforms. This sampled event data is obtained from the raw seismic data held at each station. The false alarm bulletins can interfere with this process. By controlling the average rate of false alarms from all of the stations, the network level timing and location of events by detection association processing can be optimized.

Unger (1974) analyzed the methodology of optimizing threshold settings to improve the detectability of events by a network of sensors. This was done by setting up a cost function to assess the cost in network performance of detecting false alarms and of missing signals. The optimum threshold setting at a station is that setting which minimizes the total cost of both types of detection errors. In general, the false alarm rate of these minimum cost threshold settings will not be the same at every station. For example, one means of implementing the minimum cost threshold strategy is to set up target locations in areas of surveillance interest. In that case, the false alarm rate of the optimum threshold settings will depend on the following parameters: the location of targeted regions, the minimum desired magnitude event to be detected from each region, and the maximum number of false alarms that can be tolerated to avoid missing events from the region. Simulation of network operations should allow these network level threshold control parameters to be set at values which optimize the performance of the detection association processor in detecting seismic events from each region. The detection bulletins would be coded to indicate each conditional region location implied by the threshold. An obvious result of the strategy of making thresholds conditional to event location is that thresholds will be set high enough to prevent needlessly high false alarm rates due to local events. This follows from the extremely

high likelihood of detecting the targeted event. Thresholds will also be set very high on far out noisy stations due to their very low likelihood of detection. Preliminary analysis of a minimum cost threshold strategy compared to operating thresholds at a constant false alarm rate indicated that the minimum cost mode operating at the same average false alarm rate can gain 0.3 units of magnitude detection capability.

The operating characteristics of station level array detectors depend not only on threshold control but also on the signal-to-noise (S/N) ratio of events estimated by beamforming. The S/N ratio of beams depends on accurate time alignment, the relative effect of transmission attenuation on each sensor, and the relative noise level of each sensor. The same noise information used to control thresholds could be used to estimate sensor noise. The information needed to estimate the amplitude attenuation and time delays depends strongly on the location and depth of the event within the targeted region. By analyzing past events from each targeted region, systematic corrections of plane wave models for the transmission effects (e.g., amplitudes, velocity, direction, curvature, random delays, etc.) can be derived for each targeted region. Such corrections have been shown to be very effective at the Large Aperture Seismic Array (LASA) and the Norwegian Seismic Array (NORSAR) for estimating events of known location. It is not as yet known whether such corrections can significantly improve the waveform estimations of known events on small arrays or significantly improve the performance of front end small array detectors.

D. FEASIBILITY ANALYSIS OF AUTOMATIC AND SEISMIC ANALYST INTERACTIVE DATA PROCESSING

A study was performed by Sax (1974) to evaluate how automatic and analyst interactive processing is most effectively employed for surveillance operations. At the present state of the art, the detection association process severely limits the event detection capability of a network. The process is driven by front end detection bulletins sent to a central facility.

There, false alarm bulletins, large timing errors, and interfering transmissions must be eliminated effectively from the bulletins. The remaining detection bulletins can then be used to reliably detect and update event focal parameters. These updated estimates of the location, depth, and origin time are used to estimate expected arrival times of an event at each station. The arrival times must be estimated to within about one quarter minute to confidently retrieve the event's waveform from a station. To attain a low missed signal probability, front end detectors must be operated at the lowest possible thresholds. To achieve this, the detection association processor must efficiently eliminate a large number of false alarms. It is anticipated that, to attain the most efficient elimination of false alarms, the detection association processor will need to be operated in the automatic mode with a sufficiently well designed algorithm.

To analyze event data after retrieving the waveforms, it is anticipated that,due to the interpretive nature of discrimination processing, seismic analysts will be needed. These analysts will need to turn over programs efficiently with results displayed at each step. Interactive graphics programs are needed to keep up with the work required to parameterize,document and classify events. At the post detection association processing stage, event waveforms sent in from different stations are deposited on a central storage unit. The waveforms from each station are then displayed for edit by an analyst. The analyst selects waveforms with visible signals and time aligns them by cursor manipulation. This is done interactively by the analyst so that the updated event location and error ellipse can be observed after timing each waveform. Large timing errors can be detected by large changes in the size of the error ellipse. Such problem waveforms can be re-timed or deleted if large apparent timing errors are unresolved. Another user option is to pick possible later phases, especially, nearly time coincident pP phases. As each depth-phase (pP) is picked, the old and new value of the depth of

focus, origin time estimate, and standard deviations are displayed. Convergence of the error ellipses can be used for much more accurate determination of the focal parameters, especially depth of focus.

After accurately determining the focal parameters of the event, the large S/N waveforms can be selected and corrected for the ground displacement system response, and for absorption. Each waveform can be classified as positive or negative first motion, with the results stereo plotted to estimate the source mechanism.

The final step of the post detection association process is for the seismic analyst to reduce the waveforms to one or several to be analyzed by the event classification analyst. The event classification analyst interactively performs extensive discrimination analysis to classify the event as an earthquake, as a possible explosion, as a multiple explosion, or as a possible explosion hidden by the coda of an earthquake. For routine event classification analysis, statistical discriminants such as M_s versus m_b and variable frequency magnitude are measured in order to detect possible explosions. These statistical discriminants are supplemented with complex cepstrum analysis to detect explosion echo delays, the reflection coefficient of the echo, the displacement waveform with the echo removed, and the log-log spectrum on which the analyst picks the long-period amplitude and corner frequency. Also, provision is needed to analyze multiple explosions. It is expected that the routine event classification analysis will be performed in considerably less than one-half hour per event. Since there is so much of this analysis which is also highly interpretive, it is anticipated that it must be done in the analyst-computer interactive mode given our present state of the art.

Inevitably, there will be priority events from areas of high surveillance interest which will require extended event classification processing. This will take considerably more interpretation time and more

data analysis than routine event classification processing. For such cases a regional file will be opened to document possible treaty violations, and to analyze and evaluate strategically located earthquakes which may present possible opportunities for hiding explosion sources. It is anticipated that a need exists for the capability of handling data collection for such cases at a rate of approximately one per day. This task would require that a research seismologist interactively retrieve the interesting event waveforms and other associated nearby events for comparative analysis. An important support task for analyzing interesting events is to collect raw sensor data of considerable time duration from backup tapes. These extended waveform files should be available for deposition in the data bank as interesting event files within something like twenty-four to forty-eight hours after the event occurrence. It is reasonable that data supporting interesting events will be held for a specified period of time on special event tapes. These would be batch processed until a final classification is obtained. It is anticipated that backup tapes holding the raw sensor data will be held at the station levels for at least several months before recycling.

E. SYSTEM DESIGN ANALYSIS BY SIMULATION

To be able to perform functions in the surveillance mode, it is necessary to develop fault free codes for all of the automatic and interactive processes involved in detecting events. The capability to perform a function, in the surveillance mode, can be evaluated by realistically simulating the workload handled by each process. When feasible, this is done by analyzing seismic event data and seismic noise data. If such data is not available as in the case of hypothetical future network configurations, it is necessary to realistically simulate earth seismicity and noise as well as the system function to be evaluated. This is done by means of computer generated Monte Carlo realizations from representative statistical distributions.

Statistical distributions functions and, in some cases, simulation models were used to generate the effects of event occurrences, transmission, and the operation of automatic system functions such as station detectors and detection association processors. Shoup and Sax (1974) constructed simulators to model the earthquake seismicity and transmission of P waves, pP, and several other dominant compressional wave phases. Also an algorithm was used to generate the statistical fluctuations due to the coda of earthquakes. The model used to generate coda was based on observations of the decay characteristics of earthquakes. Station detectors were simulated by controlling the average false alarm rate of each detector level, e.g., of one false alarm per hour. The required threshold to attain the prescribed false alarm rate is an output of the station detector simulator. The event timing errors were simulated by modeling a special type of event complexity factor: the time delay from first motion to the maximum signal peak. Timing errors were generated by automatically simulating noise detection by backing up from the signal peak to what was detected as noise preceding the signal. From all of the world-wide stations the detection bulletins due to false alarms, P phases, later phases and coda were printed and copied on tape. From this information, the estimated performance and precision of the simulated power detectors could be assessed.

In order to develop suitable codes for automatic detection association processing, the above tape containing world-wide station detection bulletins was used to drive a baseline model detection association processor. The baseline procedure used was to detect overlapping location error ellipses, update the location, and perform logical tests to eliminate false and redundant information. The results indicated that, although the bulletin information could be used to locate events and retrieve data, serious problems were encountered by overloading buffers and occasionally committing logical errors in the association process. Performance was thereby degraded by 0.3 magnitude units of detection capability and by the high rate of about twenty-

five erroneous waveform retrievals per day. Snell and Sax (1976) developed a more advanced model of the same automatic detection association processor. This was accomplished through repeated simulations and diagnoses of results. Performance evaluation of detection association was done by comparing detection association process locations to the known location of simulated events, for all events which exceeded threshold at four or more remote stations. The new model detection association processor demonstrated almost no loss of magnitude detection capability. This result was obtained at an error rate of about three erroneous waveform retrievals per day and at constant front end detector false alarm bulletin rate of twelve per day per remote station. The original baseline detection association processor was shown to perform optimally with remote stations operating at the twelve per day bulletin false alarm rate. Since the new model performs so well, the false alarm rate of front end detectors can obviously be raised substantially. This will improve the overall system detection capability. The optimum value of this rate has not as yet been determined by simulation.

After retrieving event waveforms, the rate at which the event data must be routinely interpreted is expected to range from one to five events per hour. To keep up with this flow of event data, seismic interpreters must process between two and four events per hour. To keep the maximum event processing delays reasonably low, event processors should be designed to achieve rates close to the upper limit but with options for more thorough processing if the workload will permit it. It is also anticipated that for recovery purposes, at least one backup graphics processor will be available to work off any occasional large backlog of event data. During normal periods, this extra graphics processor would be available to create special data files and to perform extended event classification analysis of the interesting events.

To normally maintain small backlogs and to otherwise maintain recoverability from system overloading, it is necessary to provide the seismic

analysts with computer graphics capability to interpret the seismic data. It must be possible for the seismic data analyst to create required graphics supported interactive procedures by means of a convenient special seismic command language. If the graphics processes are properly designed, the analyst can efficiently select data and processing tasks, input parameters, perform time series measurements, and recover conveniently from his own interpretation errors. The proper design of the seismic graphics processor needed to perform any analyst-driven surveillance function requires thorough understanding of the surveillance problem, the associated seismology, and the efficient numerical algorithms needed for the time series analysis. These must be integrated into a top down design by the principal scientist familiar with the above requirements working in close conjunction with one or more persons who perform the system analysis, the computer science, and the software programming. From planning through to final implementation and demonstration, it is usually necessary that these skills remain integrated and coordinated as a team effort.

In operating a surveillance system it is anticipated that at least three seismic analysts are needed in the loop required to carry through data acquisition, interpretation, and deposition of a documented event report into the seismic data bank. Initially, event waveforms are held on a central storage element after automatic retrieval by the detection association processor, the station processors, and the communication processors. The post-detection association seismic analyst selects usable waveform data, aligns the waveforms, picks later phases such as pP, and accurately determines focal information. As a final step, the analyst reduces the aligned waveforms to one or several waveforms to represent source ground motion. At this point the routine event classification seismic analyst identifies the event as an earthquake, a possible explosion, or an interesting event requiring further research investigation. A research support seismic analyst performs quality control on the resultant event waveforms and information and

deposits the classified events into a seismic data bank. This analyst supports events of special interest by retrieving additional sensor data and associated event data. Separate files are set up for events of special interest, and these are possibly also deposited in the seismic data bank.

To establish some of the interactive graphics capability needed to support the surveillance functions of seismic data analysts, Ringdal and Shaub (1974) developed and demonstrated an interactive long-period seismic processing system. They developed a high level special purpose seismic command language for fetching seismic data and performing any desired sequence of interactive computer programs on the data. Their system can be used to create data processing procedures by performing serial or branched sequences of commands. Each command allows the seismic analyst to reference video displays of data and information and interact through a keyboard to guide the next processing step. By selecting appropriate processing steps, the seismic data is manipulated to perform filtering, magnitude measurement, and group velocity analysis. These are some of the useful tools which can be used by the seismic analyst to perform routine event classification processing. In particular, filtering improves detection of the long-period event waveforms. By measuring the long-period magnitude of Rayleigh waves and Love waves, most explosions can be separated from earthquakes. The two random populations are separated by about 0.7 to 1.0 magnitude units with standard deviations of from 0.3 to 0.45 magnitude units. The detectability is approximately $1.0/0.33 \approx 3.0$. Given the detectability of about 3, at the 90% level of explosion detection, it is expected that approximately 5% of the earthquake population will be erroneously classified as explosions based on M_s versus m_b criteria alone. At the 50% level of explosion detection, the error rate will be about one per thousand. Clearly, better operating characteristics than these are needed to effectively monitor a test ban treaty. The dependence on M_s versus m_b criteria alone is further complicated by repeated observations of explosion-like earthquakes from certain regions. Not only is this criteria

region dependent but at teleseismic distances it is only reliable for large events of the order of 5.0 and greater due to the severe limitations imposed by long-period seismic noise on the detectability of explosion surface waves. The above cited operating characteristics are conditional on detecting both the surface waves and the bodywaves of both classes of events.

Our present research is motivated by the need to effectively extend analyst interactive discrimination capability to lower magnitude events, e.g., on the order of 4.0 magnitude at teleseismic distance, and the need to more reliably discriminate explosion events from earthquakes. Bache et al. (1975) thoroughly evaluated a short-period variable frequency magnitude discriminant described by Savino and Archambeau (1974), Bache et al. (1974), and Archambeau et al. (1974). The results of the evaluation of the short-period variable frequency magnitude discrimination techniques indicated that approximately the same operating characteristics as M_s versus m_b discrimination could be extended to lower magnitude events.

Any statistical method of discriminating earthquakes and explosions such as M_s versus m_b measurements or short-period variable frequency magnitude measurements will generate out of the earthquake population occasional and possibly, from some locations, consistent false indications that an explosion has occurred. Another even more serious type of error is discriminants generated out of the presumed explosion population which are consistently misidentified as earthquakes. In order for the surveillance system to be credible, the rate of such alarms must be adequately controlled as part of the discrimination process.

In order to improve the operating characteristics of statistical discriminants, the statistical methods should be backed up by a capability to separate the direct transmission and free surface echo. This provides the means of directly verifying that an event, statistically indicated as an

explosion, satisfies the necessary conditions of an explosion, i.e., an echo reflection coefficient close to minus one, a reasonable time delay for a shallow focus contained explosion, and a reasonable direct transmission waveform shape and spectrum.

SECTION II

DESIGN SPECIFICATIONS OF THE SHORT-PERIOD EARTHQUAKE/ EXPLOSION DISCRIMINATOR (SPEED) AS AN INTERACTIVE GRAPHICS EVENT CLASSIFICATION MODULE ON THE PDP-15

A. INTRODUCTION

The Short-Period Earthquake/Explosion Discriminator (SPEED) processing module has been integrated into the Interactive Seismic Processing System (ISPS) graphics capability on the PDP-15 computer. This section provides background information, data preparation procedures, and a description of the SPEED module.

In Subsection B, the ISPS is briefly discussed in terms of a world-wide surveillance system. The data preparation procedures - the reduction to one or at most several event waveform representations to be used in the discrimination processing - are described in Subsection C. A thorough description of the operation of the SPEED module, with its real cepstrum and Variable Frequency Magnitude (VFM) and corner frequency analysis procedures is given in Subsection D. A general summary of the algorithms used by SPEED are shown in Subsection E. Finally, hardcopy examples of the SPEED graphics displays are shown in Subsection F.

B. CONTEXT OF IMPLEMENTING A WORLD-WIDE SEISMIC SURVEILLANCE SYSTEM

The overall objective of a seismic surveillance network is the detection, location, and identification of seismic events on a world-wide basis. To achieve this objective, there are six broad functional categories that need to be considered. In Table II-1, each of the broad functional areas

TABLE II-1

SURVEILLANCE NETWORK FUNCTIONS
(PAGE 1 OF 2)

Functional Category	Information Generation and Processing
Data Collection	• Deploy remote sensors. • Data collection processing. • Hold sensor data for retrieval. • Edit event waveforms from the sensor data which are held for retrieval.
Station Event Detection	• Generate station detection bulletins.
Communications and Data Lines	• Retrieve raw data from sensors to disk or station collection platforms. • Detection bulletin from data collection platform to central storage element. • Event waveforms from station storage element to central storage element. • Event parameters and representative waveform from central storage element to data bank. • Backup data tapes. • Messages for command and control of central and station operations.

TABLE II-1

SURVEILLANCE NETWORK FUNCTIONS
(PAGE 2 OF 2)

Functional Category	Information Generation and Processing
Retrieval of Event Waveforms	• Control retrieval of event data from station storage elements by generating event locations and origin times from detection bulletin information. • Generate accurate focal parameters from event data sent in from stations. • Classify events by discrimination analysis of representative event waveforms.
Storage and Retrieval of Event Parameters and Data	• File event bulletins and representative waveforms. • File hourly noise parameter measurements. • Update regional reference event file. • Update and consolidate index and files for long-term storage of events.
System Control and Upgrade	• Stations and network performance evaluation. • Prediction and control of system overloading. • Fault detection, maintenance and repair control. • Start up and updating of new model function processors. • Updating reference event files. • Research support by data base generation.

are defined. They are broken down into specific function processes which generate the files of information needed to control the operation of a seismic surveillance network.

The hardware configuration of a seismic surveillance network is shown in Figure II-1. Arrays or regional deployments of short-period and long-period sensors are linked by communications to a data collection platform. At the data collection platform, the data are formatted, multiplexed, and held temporarily on a station disk and permanently on a backup tape. Station detection functions are immediately performed upon this sensor data held on the station disk. Independently of other stations in the network, each station detection processor detects the possible arrival of seismic events. These detections are described on detection bulletins which are immediately sent by a communication link or data line from the data collection platform to a central facility. At the central facility the detection bulletin is decoded by the COM processor and queued on the central disk system in a detection bulletin file. On a first in/first out basis, the detection bulletins fill the work space of an automatic detection association processor. This processor uses information obtained from the incoming detection bulletins to generate output which includes locations and origin times of events. The event focal parameter estimates are used at this point to automatically request time windows of data containing the event waveforms. These requests to retrieve a seismic event waveform data are sent by communication links or data lines to the station data collection platforms. At each station data collection platform, the desired event waveforms are automatically retrieved from a disk storage element which is holding the seismic data for up to six hours. The retrieved event waveform data are sent back as data packets during periods of time that the communication link or data line is available (e.g., between transmissions of detection bulletins). The waveform data are received at the central facility by a central communications processor which files the waveforms on the central storage element under supervision of a central disk system.

SS	Seismic Sensors	DAP	Detection Association Processor
SDP	Station Detection Processor	ECP1	Event Classification Processor (Discrimination)
COM	Communication Processor	ECP2	Event Classification Processor (Special Events)
		SCP	System Control Processor

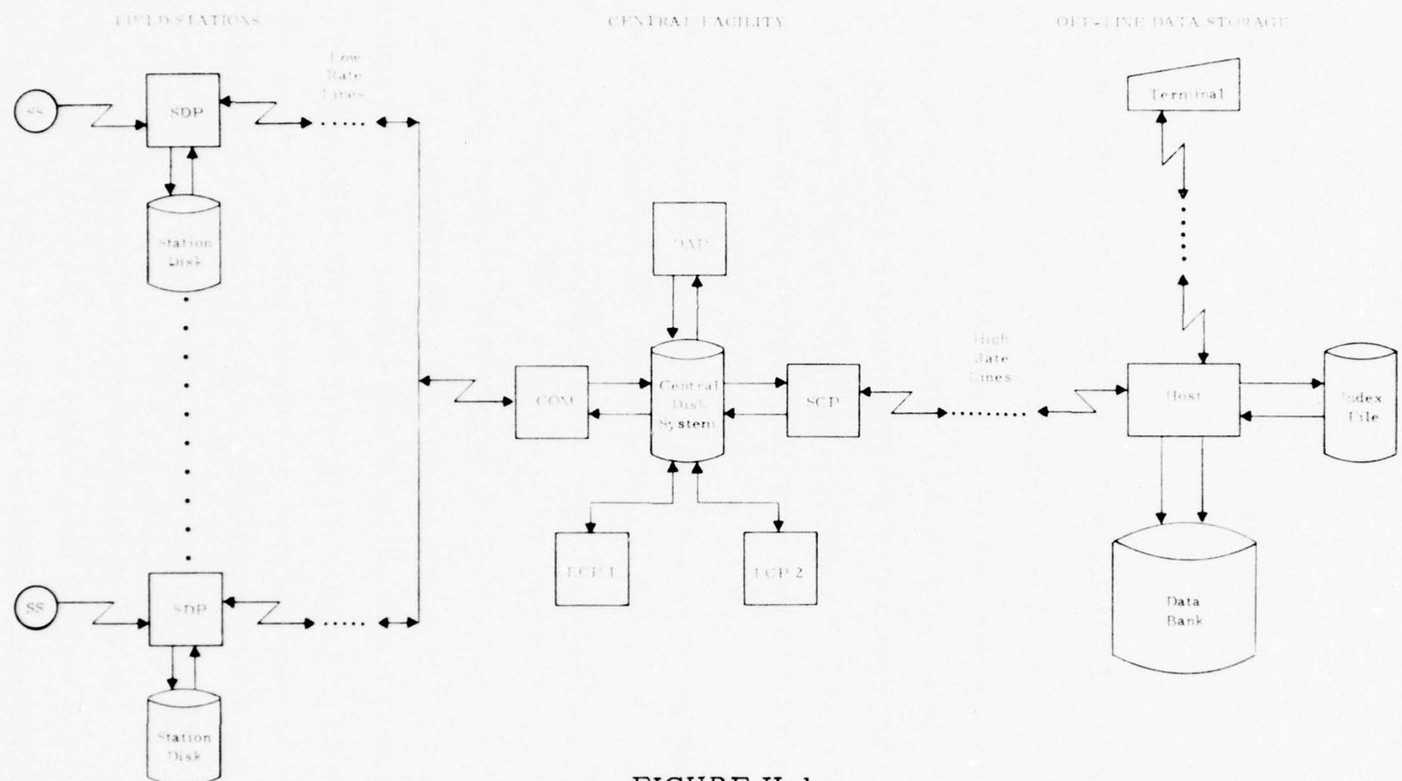


FIGURE II-1

SEISMIC NETWORK HARDWARE CONFIGURATION

The event data stored on the central disk system consists of many channels. To be practical, discrimination processing must be fast enough to keep up with the data flow generated by the surveillance network. The reduction of the multi-sensor representations of an event to one or several representations for discrimination processing is described in the next section.

C. DATA PREPARATION FOR DISCRIMINATION PROCESSING

The event waveform file stored on the central disk system consists of one or more sensors or signal estimates from each station receiving the event. These must be reduced to one or at most several event waveform representations to be used for discrimination processing. In order to rapidly classify the event as a possible explosion or earthquake, the discrimination processing must be rapid enough to keep up with data flow on the order of 50 events per day. Allowing a utilization of 50% of computer capacity, the processing time per event for all routine event classification processing should be on the order of 15 minutes. Specific algorithms should therefore consume no more than several minutes of the event processing time. In order to reliably classify the events, there should be considerable diversity of discrimination processing readily accessible to the analyst. In particular, short echo time determinations by cepstrum analysis should be mandatory in order to reduce false identification of earthquakes to an acceptably low false alarm rate for events of magnitude greater than the minimum targetted for surveillance. Also, some form of the variable frequency magnitude method should be used, provided that discrimination capability comparable with M_s versus m_b, can be obtained with better detectability of lower magnitude events.

At the station platform level, multi-sensors such as arrays are reduced to a single station waveform representation. Since very accurate arrival time measurements are not required at this level, the reduction

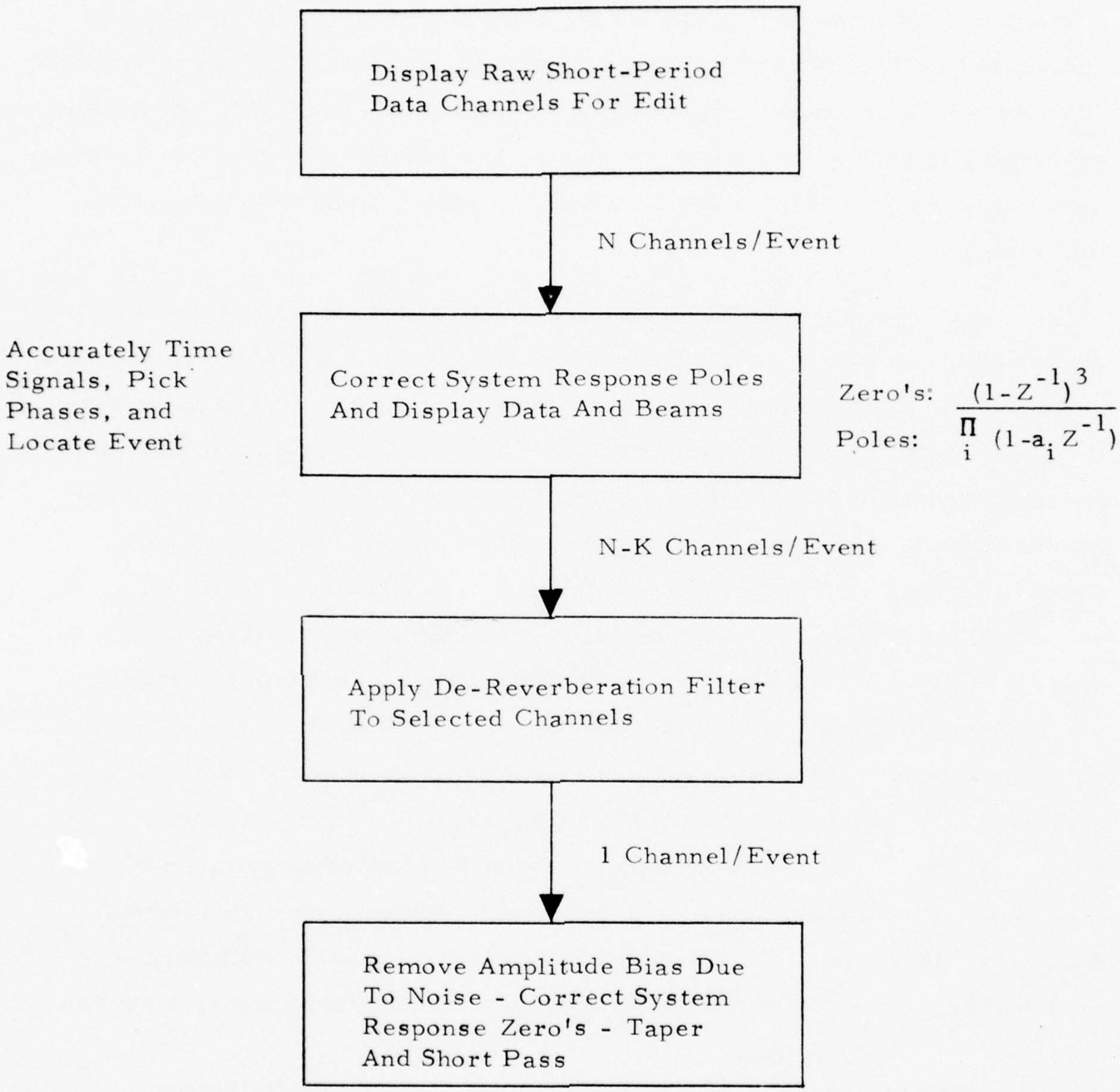
process can be carried out automatically. The need for reduction also occurs at the post DAP level, where station waveforms are accurately timed by an analyst and precise focal parameter estimates are made. A post DAP analyst edits stations with seismic information, signal centers the event, and invokes processing to reduce the station waveforms to a single event waveform representation to be queued for discrimination processing by the event classification analyst.

A requirement for designing data reduction algorithms for the above applications is to produce event estimates with an undistorted spectrum of the event. Beamforming is in many cases inadequate, as deviations from the assumption of plane waves in an infinite homogeneous medium (the model for beamforming) produces severe attenuation of high frequencies which degrades the data for short-period discrimination processing. A method of event estimation based on multi-channel complex cepstrum estimation is shown in Figure II-2. The critical technical points in the development are to prevent aliasing of the phase between channels, and to develop the optimum method of automatically weighting channels in computing the average log amplitude and phase of the representative waveform. In Figure II-2, it is also shown that the waveforms are corrected for spectral bias due to additive noise, and are corrected for system response to produce an estimate of broadband ground motion such as acceleration, velocity, or displacement. As a final step, single channel complex cepstral techniques such as short-pass filtering are used to reduce the extensive coda of large complex events.

D. APPLICATION OF THE INTERACTIVE SEISMIC PROCESSING SYSTEM TO DISCRIMINATION PROCESSING

The Interactive Seismic Processing System (ISPS) provides an interactive graphics capability on the PDP-15 computer located at the Seismic Data Analysis Center for the purpose of detecting and analyzing seismic waveforms. It currently consists of a system supervisor and five stand-alone

DATA BASE INPUT PREPARATION



J EVENTS ON TAPE WITH 1 WAVEFORM PER EVENT

FIGURE II-2

REDUCTION OF WAVEFORMS TO PARAMETERS
AND A SINGLE WAVEFORM REPRESENTATION OF THE EVENT

processing modules as shown in Figure II-3. In particular, they are defined as follows:

SUPVSR - The system supervisor to control processing module execution within the CRT console environment.

DPSCAN - A processing module to catalog and display waveforms from the large capacity disk.

SELEV - A processing module to select any event, station, component, or time window for analysis.

FILTER - A processing module to perform general signal analysis functions.

GRVEL - A processing module to generate long-period dispersion curves and fundamental mode source spectrum.

SPEED - A processing module to perform short-period earthquake/explosion discrimination utilizing cepstrum, variable frequency magnitude, and corner frequency techniques.

The continuing methodology associated with ISPS is the simulation of analysis functions to be performed by processors comprising a world-wide seismic surveillance system. A description of how this simulation is achieved is given as follows:

- Research and development of analysis software for detection, association, and classification of seismic events. The components of this software are computational subroutines coded in FORTRAN IV, having minimal or non-existent I/O requirements. This insures that these routines are machine independent and are easily maintained.

- Imbedding this analysis software in an environment simulating that of a surveillance system when each processor is driven

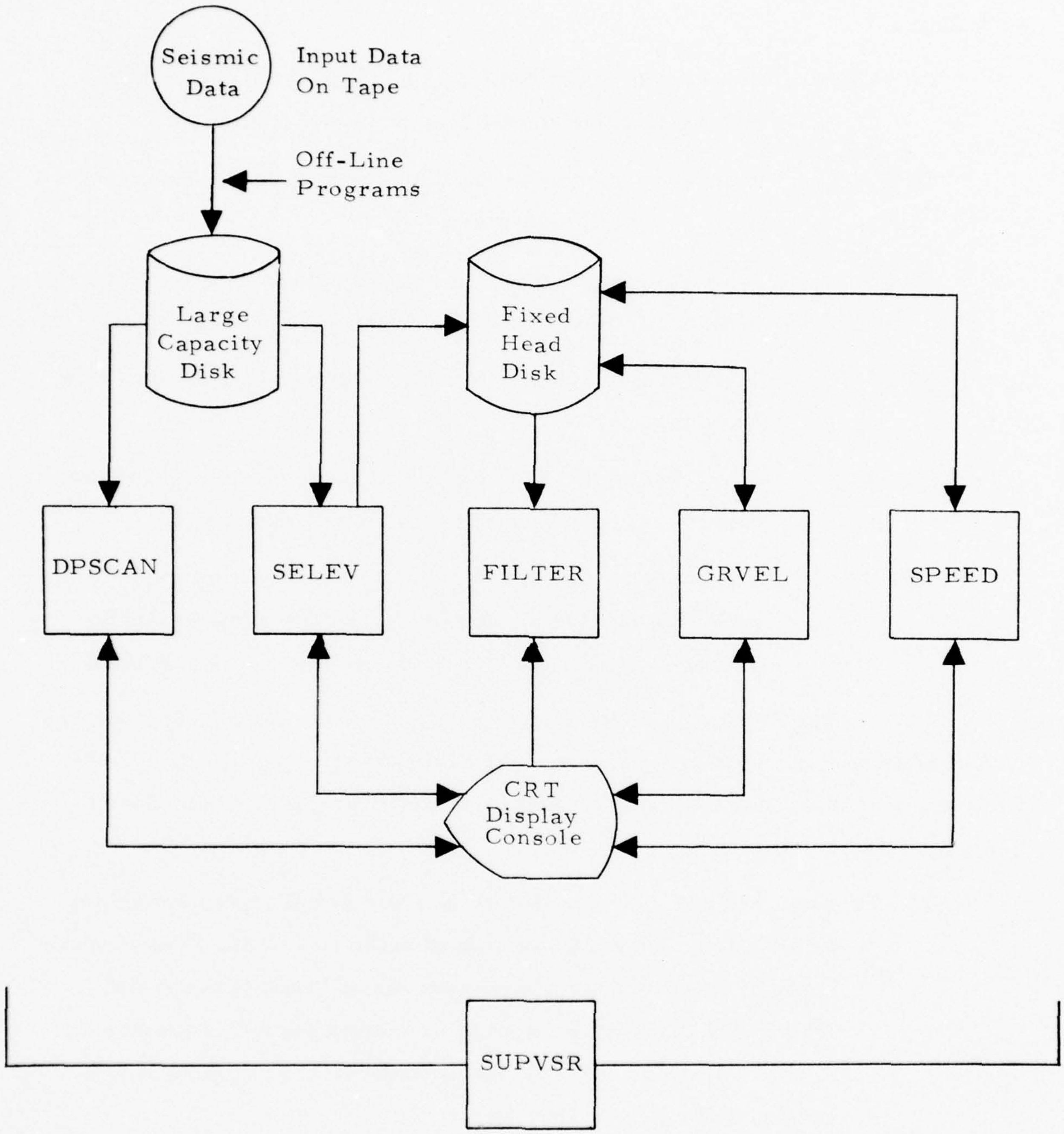


FIGURE II-3

INTERACTIVE SEISMIC PROCESSING SYSTEM (ISPS)
INFORMATION FLOW

by a special purpose operating system which supports the following:

- A console device to serve as the physical interface between computer system and analyst, capable of communicating and displaying symbol strings and graphic images

- A command language to control execution of analysis functions assigned to the processor

- An interpretive high level seismic programming language permitting the analyst to design and execute special functions on-line. The language will have the capability to access, perform computation upon, and display data for evaluation and analysis purposes

- Automatic processing modes providing for execution of analysis functions with minimal intervention required by the analyst once processing procedures have been standardized.

• Insuring that the ISPS environment accurately simulates that of an actual processor by incorporating a top-down design stressing the following:

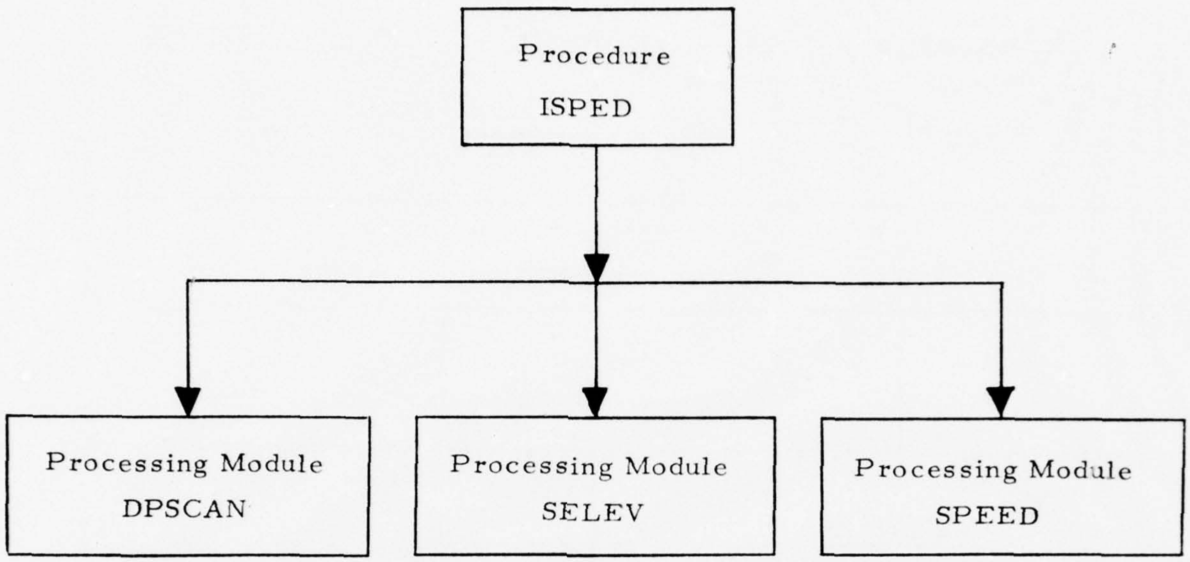
  - Operational flexibility
  - System reliability and recoverability
  - System maintainability and extendability.

This effort was given high priority for two main reasons. First, interactive processing systems must be capable of accepting erroneous input without requiring a restart of the entire analysis procedure in question. Secondly, the system should be extendible so as to maintain its applicability as advancements in seismic processing are realized.

A new analysis function designated SPEED has been developed to simulate discrimination processing by utilizing CEPSTRUM and Variable Frequency Magnitude (VFM) techniques and corner frequency. SPEED will be demonstrated as a processing module which has been incorporated into ISPS. Figure II-4 illustrates the utilization of a procedure named ISPED to perform discrimination processing within the ISPS environment. ISPED defines a processing module execution sequence which includes the modules DPSCAN, SELEV, and SPEED.

The function SPEED consists of three discriminant calculations. In Figure II-5, the first one of the discriminant functions performs cepstrum analysis; the second, variable frequency magnitude (VFM) analysis, and the last, corner frequency analysis (CF). The three functions of SPEED - cepstrum, VFM, and CF - are described as follows:

- The cepstrum analysis is subdivided into three interactive subroutines. SUB1 adjusts start time or exponentially tapers the data as desired by the analyst. SUB2 separates the signal and echo by trial-and-error deconvolution. SUB3 generates a residual seismogram and sets up CEPSTRUM to pick later phases (e.g., multiple explosions), if desired by the analyst. The statistics generated for discrimination are the time delay of the echo, reflection coefficient, correlation coefficient between the echo and the first arrival, and the residual noise when the estimate of the echo and first arrival are removed from the original data.
- The VFM analysis in SUB4 removes the exponential taper from the first arrival signal estimate derived from CEPSTRUM. In SUB5 it computes the high and low frequency dependent magnitudes from the corresponding semi-log-signal spectrum display corrected for absorption.



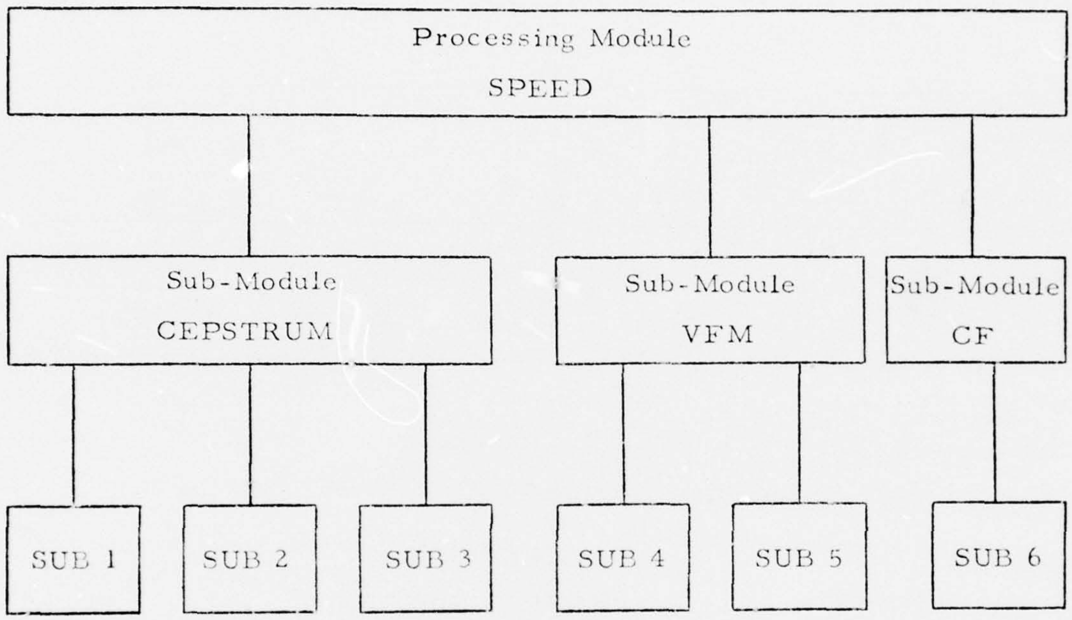
The procedure ISPED may be created and executed at the Interactive Console by the following commands:

....	. CREATE ISPED
1.0	. PERFORM DPSCAN
2.0	. PERFORM INTERUP
3.0	. PERFORM SELEV
4.0	. PERFORM INTERUP
5.0	. PERFORM SPEED
6.0	. PERFORM INTERUP
7.0	. #S
....	. PERFORM ISPED.

FIGURE II-4

IMBEDDING SPEED WITHIN ISPS ENVIRONMENT

SHORT-PERIOD EARTHQUAKE/EXPLOSION DISCRIMINATOR



SUB 1 - Conditions Data For Cepstrum Analysis

SUB 2 - Separates Signal And Echo

SUB 3 - Computes Residual Seismogram

SUB 4 - Conditions Data For Spectral Analysis

SUB 5 - Computes Variable Frequency Magnitudes

SUB 6 - Computes Corner Frequency And Amplitude From Log-Log Spectrum Plot

FIGURE II-5

SHORT-PERIOD EARTHQUAKE/EXPLOSION DISCRIMINATOR

- The CF analysis in SUB6 can measure up to four corner frequencies, amplitudes, and roll-offs from the log amplitude versus log frequency spectrum of the signal transmission corrected for absorption.

The software configuration of the interactive CEPSTRUM processor is shown in Figure II-6. A signal is input to SUB1, and the data and real cepstrum are displayed. The complex log spectrum is calculated and held in workspace along with the data. If the analyst is not satisfied with the start time of the data selected with the SELEV module, he may input other trial time shifts until he is satisfied. The analyst then presses the taper button until he is satisfied with the appearance of the data and the real cepstrum. If he tapers too much, he recovers by pressing the replace taper button. After data conditioning is finished, the analyst presses the hardcopy-exit button and a Calcomp plot tape of the results is prepared. Should the analyst desire, the data may be plotted while he is performing other analysis. Following preparation of the plot tape, control is passed to SUB2. In SUB2, the cepstrum and conditioned data display are refreshed. The analyst presses the deconvolve button. He then inputs trial values of the reflection coefficient and time delay, examining the effect of deconvolution on the data and cepstrum. When satisfied with the resultant deconvolution, he presses the load button which computes and saves the echo and allows him to short pass the signal. Smoothing of the log spectrum of the signal estimate with a Bartlett window provides a short pass filter. This is used to separate the earthquake pulse from the echo. If the analyst presses the smooth button one too many times, he can recover the preceding state by pressing the replace smooth button. By pressing the load button again, the smoothed signal is saved and the echo is retrieved to be similarly short passed. The load button is pressed a third time to form the reconstructed signal with its echo. Whenever the load button is pressed, a display of the conditional data, the signal, the echo, and the reconstructed signal are shown from top to bottom as they become available

- Separates signal from coda and noise
- Separates the direct path and free surface reflection
- Estimates first pulse direct path and echo
- Sets up SPEED to compute multiple events
- Computes discriminant statistics

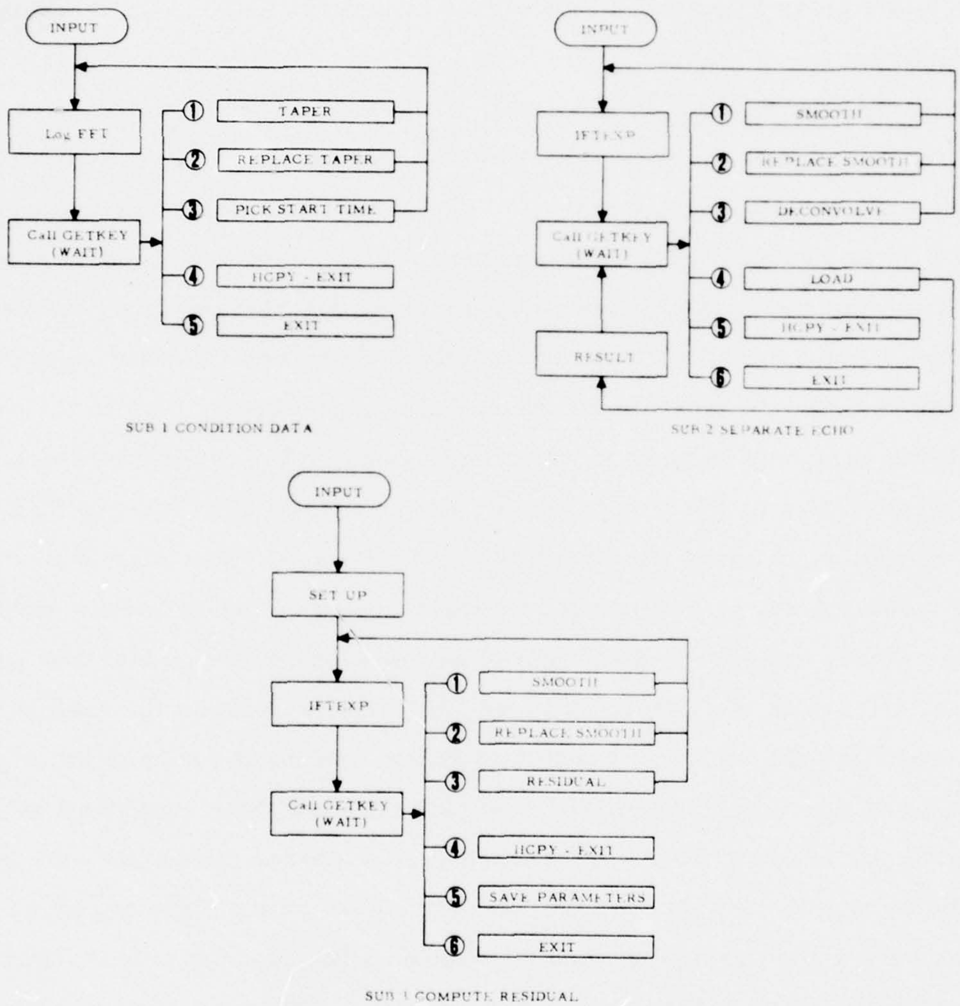


FIGURE II-6

INTERACTIVE PROCESSOR SPEED MODULES
CEPSTRUM

by the above analyst processing. After finishing SUB2 processing, the analyst presses the hardcopy-exit button to plot the results, and passes control to SUB3. In SUB3, the reconstructed seismogram is subtracted from the conditioned data to produce a residual seismogram with the first phase signal and echo removed. A later phase is picked by means of trial shifts of the waveform similar to that done in SUB1. By pressing the SAVE PARAMETER button, the residual signal, which was shifted to the front of the seismogram, is replaced as input to CEPSTRUM. In this way, up to four phases (e.g., multiple explosions) can be successively analyzed by the analyst. In the preceding operations, discriminants such as echo time, reflection coefficient, correlation coefficient, and residual signal-to-noise ratio are calculated and included in the hardcopy as annotations.

The software configuration for variable frequency magnitude (VFM) calculation is shown in Figure II-7. Initially in SUB4, the smoothed and tapered signal estimate from CEPSTRUM is displayed along with the real cepstrum. The data are conditioned by inverting the exponential tapers put in by the analyst to condition the data for the cepstrum analysis. Roundoff errors which may occur at the end of the record are zeroed out by pressing the zero button. The signal may be short pass filtered by pressing the smooth button. Control is then passed to SUB5 and the real log spectrum of the signal estimate is displayed. This spectrum may be smoothed incrementally by a Bartlett window and may be corrected for absorption. Magnitude measurements are initiated by pressing the measure magnitude button. The average log amplitude is computed in a central window of the log spectrum. The change in log amplitude between a marked low frequency and the average and a marked high frequency and the average are computed as VFM discriminants. If the signal is obviously noisy at the specified low or high frequency, a cursor is used to pick points on the spectrum near the desired frequency outside the frequency range of the noise. By linear extrapolation, the magnitude difference

- Operates on signal estimate output of cepstrum program
- Inverts the taper which was applied to the signal
- Add zero's to end of signal model, if needed
- Picks two low and high frequencies to read magnitude
- Linearly extrapolates to obtain low and high frequency magnitude at desired frequencies

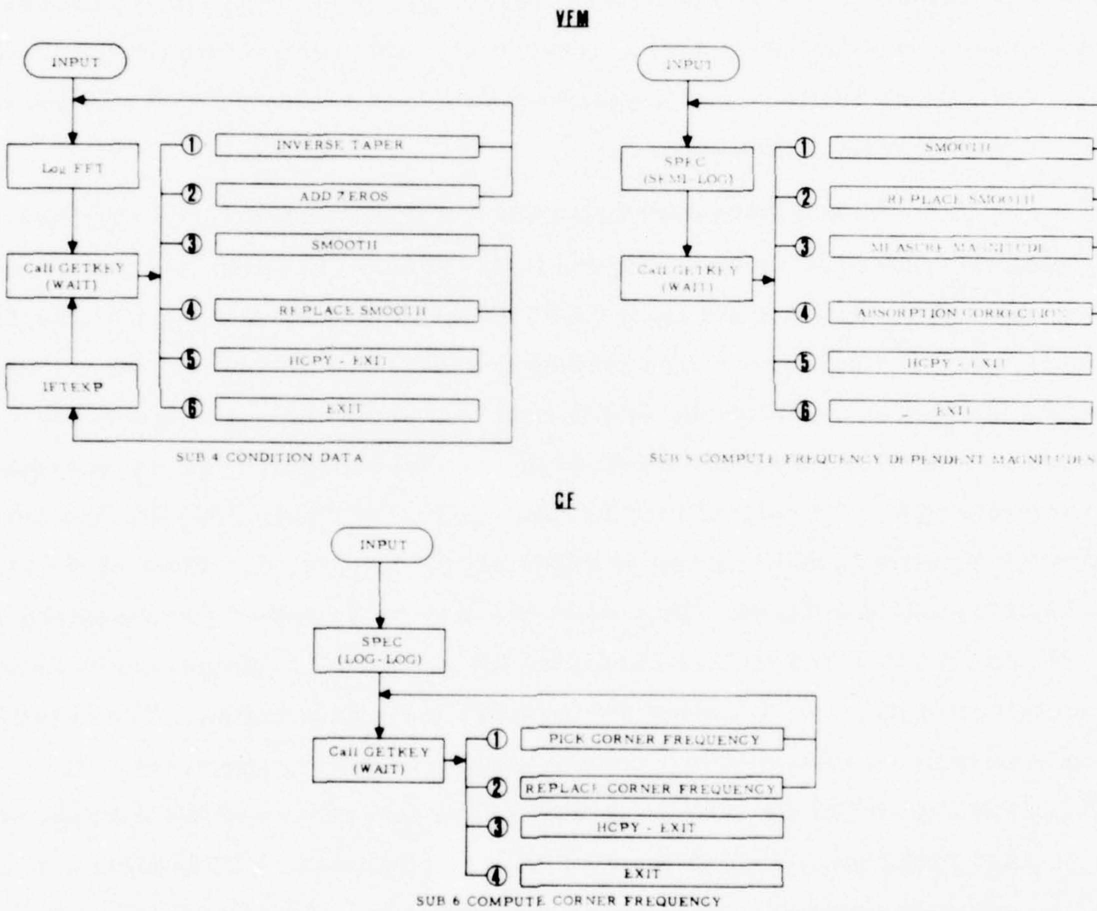


FIGURE II-7

INTERACTIVE PROCESSOR SPEED MODULES
VARIABLE FREQUENCY MAGNITUDE AND CORNER FREQUENCY

at the desired high or low frequency is computed. Our experience indicates that this option is usually not needed.

The software configuration of the corner frequency (CF) calculation is also shown in Figure II-7. The real log spectrum versus frequency computed in SUB5 is transformed into a log spectrum versus log frequency display. Corner frequencies, magnitudes, and roll-offs are measured by pressing the corner frequency button. A cursor is used to pick two points of the spectrum on each side of the desired corner frequency. The corner frequency is then automatically picked as the intersection of the two straight lines through the left and right pair of points. This process may be repeated up to four times. The resultant corner frequency, amplitude at the corner frequency, and roll-offs on the left and right side of the corner are displayed for each corner picked. If the analyst is not satisfied with a picked corner frequency, it may be erased by pressing the replace corner frequency button. After the analyst finishes picking corner frequencies, the hardcopy-exit button can be used to produce a Calcomp plot tape.

An exit button is present in all of the subroutine modules described above. This is a recovery procedure which re-starts the subroutine module in case of irrecoverable errors or failures. It is unlikely that this option will be needed because of other internal provisions for error recovery.

E. ALGORITHMS

1. Data Preparation

a. Align and Display Data

A partial list of symbols used in the following derivation of algorithms is given here.

T	- represents uniform time between sampled data points.
N	- number of time sampled points.
n	- sequence number of real time domain data points.
k	- sequence number of complex frequency domain data points.
Δf	- uniform frequency interval between spectrum samples, $1/NT$.
$FFT(\ )$	- fast Fourier Transform operator; $FFT^{-1}(\ )$, inverse.
$d(t)$	- data; $d(nT)$, sampled data.
$Z(k\Delta f)$	- spectrum computed from sampled data.
$X(k\Delta f)$	- real part of $Z(k\Delta f)$.
$Y(k\Delta f)$	- imaginary part of $Z(k\Delta f)$.
$A(k\Delta f)$	- amplitude spectrum
$\phi(k\Delta f)$	- phase spectrum
$\Delta\phi(k\Delta f)$	- the finite difference of phase as an approximation to the differential of the phase.
$\Delta X(k\Delta f)$	- difference of the real part of the spectrum.
$\Delta Y(k\Delta f)$	- difference of the imaginary part of the spectrum.
w	- exponential taper used to derive channel Wiener weights, et al.
${}_j d_N(nT)$	- sampled noise data on j^{th} channel.
${}_j d_S(nT)$	- sampled signal data on j^{th} channel.
u	- parameter to weight ambient noise in deriving channel Wiener weights.
v	- parameter to weight coda noise in deriving channel Wiener weights.
S_j^2	- signal power; N_j^2, noise power; C_j^2, coda power used in channel Wiener weight estimates.
$C_j(f)$	- the spectrum of a linear coda operator for the j^{th} channel.
$S(f)$	- the spectrum of signal common to all channels.

$N_j(f)$ - the spectra of independent noise added to the j^{th} channel.

$\text{Log } Z_S(k\Delta f)$ - log-spectrum of signal corrected for noise bias.

$\text{Log } A_S(k\Delta f)$ - real part of log-spectrum of signal.

$\phi_S(k\Delta f)$ - imaginary part of log-spectrum of signal.

$\text{Log } A_S^*(k\Delta f)$ - corrected for absorption.

$\phi_S^*(k\Delta f)$ - corrected for absorption.

$S(k\Delta f)$ - exponentiated spectrum corrected for absorption.

$d^*(nT)$ - estimate of signal pulse corrected for absorption.

$R(Z)$ - system response

$R_1(Z)$ - part of system response due to poles.

$R_2(Z)$ - part of system response due to zeros.

α_j - roots of poles of system response.

γ_j - scale factors of system response associated with poles.

$d'(nT)$, $d(nT)$ - corrected for poles of system response.

$\text{Log } A_S''(k\Delta f)$ - binomial smoothing of $\text{Log } A_S(K\Delta f)$.

$\phi_S''(k\Delta f)$ - binomial smoothing of $\phi_S(k\Delta f)$.

Re( ) - real part of complex elements of an array.

Log{ } - logarithm of complex elements of an array.

( ) → ( ) - the elements generated by operators on the left side replace the elements of the array on the right side.

DISPLAY( ) - display of arrays designated in parenthesis.

T/Q - travel time divided by absorption Q when used in Strick's absorption formula.

Given the ray parameter dt/dr (seconds/kilometer) and direction θ of the incident wave,

$$dt/dx = dt/dr \cos\theta$$

$$dt/dy = dt/dr \sin\theta \qquad \text{(II-1)}$$

and the travel time delay from the center of the array (x_o, y_o) to a sensor position (x_i, y_i) is:

$$\Delta t_i = (dt/dx)(x_i - x_o) + (dt/dy)(y_i - y_o) \, . \qquad \text{(II-2)}$$

A matrix plot of all of the plane wave aligned sensors, either filtered or unfiltered and with the signal centered, is inspected by the analyst to remove inoperative channels, noisy channels, and clipped channels.

b. Selected Channels Are Complex Cepstrum Beamformed

Acceptable data channels are timed to allow about one-half second of noise preceding the earliest apparent arrival of signal energy. From that start time, the following 512 points (20 points/second) of data are read into a signal buffer; the preceding 512 points are read into a noise buffer. An exponential taper, a^n - where n is the number of points delay from the start point - is applied to the data in the signal and noise buffer. The parameter, a, weights the cepstrum analysis more heavily toward the start time of the signal. A recommended value is 0.98 which is down to 0.13 after 100 points. If desired, smaller values can be applied to the noise buffer for more conservative estimates of the interfering noise power. We used 0.98 for both buffers. The signal buffer and noise buffer were filled out with 1536 zeros so that each buffer contained 2048 points.

An $N = 2048$ point fast Fourier Transform (FFT) was applied to the signal and noise buffer producing a signal and noise spectrum, each of 1023 complex points plus 2 real points at zero frequency and the Nyquist frequency (10 Hz). The log-spectrum is computed of the spectral data in the signal and noise buffer. Given the data, $d(t)$, as uniformly sampled signal or noise at period T, the spectrum sampled at frequency interval $\Delta f = 1/NT$ follows:

$$Z(k\Delta f) = FFT(d(nT)) \qquad n = 1, \ldots, N.$$

$$= X(k\Delta f) + i\,Y(k\Delta f) \qquad k = 0, \ldots, N/2$$

$$\text{Log}\,(Z(k\Delta f)) = \text{Log}\,A(k\Delta f) + i\phi(k\Delta f) \tag{II-3}$$

where

$$A(k\Delta f) = \left(X(k\Delta f)^2 + Y(k\Delta f)^2\right)^{1/2}$$

$$\phi(k\Delta f) = \tan^{-1}\,(Y(k\Delta f)/X(k\Delta f))$$

and

$$\text{FFT}(\ ) = \text{functional Fourier transform operation.}$$

The phase $\phi(k\Delta f)$ is complicated by rapid changes in phase from one frequency point to another due to unknown start time delays and influence of coda. This can cause errors in detecting the position and size of 2n jumps in the phase angle, which must be corrected to produce a continuous phase curve. To avoid this problem, the phase information is passed through as, i.e., $\Delta\phi(k\Delta f)$, a first difference operator running from $k = 1$, to $k = N/2$, where $k\Delta f$ are the corresponding frequencies running from zero to Nyquist $(N/2) \bullet (1/NT) = 1/2T$.

$$\Delta\phi(k\Delta f) = \frac{Y(k\Delta f)\,\Delta X(k\Delta f) - X(k\Delta f)\,\Delta Y(k\Delta f)}{\left(X(k\Delta f)^2 + Y(k\Delta f)^2\right)} \tag{II-4}$$

where

$$\Delta X(k\Delta f) = X(k\Delta f) - X((k-1)\Delta f)$$

and

$$\Delta Y(k\Delta f) = Y(k\Delta f) - Y((k-1)\Delta f).$$

The data on each channel $d(nT)$ are converted to a log-spectrum, where the first part is $A(k\Delta f)$ and the second part is $\Delta\phi(k\Delta f)$; and both parts are even symmetric at zero and the Nyquist frequency $(k = 0,\ N/2)$.

Each channel $\left(A(k\Delta f),\ \Delta\phi(k\Delta f)\right)$ is weighted and summed by a Wiener weight for the j^{th} channel:

$$W_j = S_j^2/(S_j^2 + uN_j^2 + vC_j^2) \tag{II-5}$$

where

$$S_j^2 = \sum_{n=0}^{N} \left[{}_j d_S(nT) \cdot w^n\right]^2$$

$$N_j^2 = \sum_{n=0}^{N} \left[{}_j d_N(nT) \cdot w^n\right]^2$$

$$C_j^2 = \sum_{n=0}^{N} \left[{}_j d_S\Big((N^* - n + 1)T\Big) w^n\right]^2$$

$u \equiv$ parameter between zero and one to weight ambient noise

$v \equiv$ parameter to weight coda measure

$w \equiv$ exponential taper, zero to less than one.

For the channel Wiener weights to be realistic signal and noise, it is recommended that w be set to 0.94 to 0.98. A value of $w = 0.95$ was used for this study, which effectively gives a signal window length of about two seconds. *Note that setting* $u = v = 0$ *provides a unity weighted beamform process.* Setting $u = 1$, $v = 0$ provides a full Wiener weighting using ambient noise. It is recommended that, since S_j^2, N_j^2 and C_j^2 are subject to statistical errors as well as bias due to timing problems, less than full Wiener weights be used. In this study, $u = v = 0$ in order to baseline our results using unity weighted complex cepstrum beamforming. It is also noted that the $\Delta\phi(k\Delta f)$ of the noise buffer contains no information of value. It, therefore, was not computed and passed through the next stage of data processing.

c. The Complex Cepstrum Beamform is Smoothed and Corrected for System Response, Absorption, and Reverberation Noise

The complex cepstrum beamform is designed to minimize the variance of log normally distributed random fluctuations of the signal due to random propagation effects and to some extent due to the additive log-normal noise factor. If $C_j(f)$ is a random propagation effect of the jth channel and

$N_j(f)$ is an additive zero mean random variate with a log normally modulated envelope, then the jth channel with common signal spectrum $S(f)$ is:

$$
\begin{aligned}
X_j(f) &= C_j(f)\, S(f) + N_j(f) \\
&= S(f)\, C_j(f)\, L_j(f) \qquad \text{(II-6)}
\end{aligned}
$$

where

$$L_j(f) = 1 + C_j(f)^{-1} N_j(f).$$

For visible signals it is expected that $|C_j(f)| \gg |N_j(f)|$. To the extent that $L_j(f)$ can be approximated as a log normal variate, beamforming over the spatial distribution of channels minimizes transmission effects of C_j and pseudo-transmission effects of L_j. The variance of the expected log amplitude of the signal and the expected phase of the signal due to such independently random transmission effects is reduced by $1/J$ where J channels compose the complex cepstrum beamform of the signal. It is noted that this type of beamforming does not directly reduce the expected means of the ambient noise as does time domain beamforming. But indirectly as the variance of the log normal distribution is lowered, the arithmetic mean amplitude of the noise will also be somewhat reduced, especially the occasional large amplitude fluctuations.

Before beamforming the log amplitude of data in the noise buffer, the power spectrum of noise was compared to that of the signal. Based on stationarity, it was expected that the power in the signal buffer should exceed the power in the noise buffer at all frequencies. In some cases due to statistical estimation errors, this was not the case. In those cases, the log amplitude of the signal buffer replaced that of the noise buffer. Thus, the average log amplitude of the data in the noise buffer was guaranteed to be equal or less than that in the signal buffer.

To correct for positive bias of the measured mean amplitude of signal, the power of the average signal was reduced by the power of the average noise as follows, where the subscripts $S+N$ and N refer to the

signal and noise buffers, respectively; the bar refers to numerical averaging over channels; and the E operator refers to the expected value, in this case, of the signal amplitude spectrum $\text{Log } A_S$:

$$E(\text{Log } A_S) = \text{Log}\left(\text{Exp}(\overline{\text{Log } A_{S+N}}) - \text{Exp}(\overline{\text{Log } A_N})\right). \qquad \text{(II-7)}$$

This expected value of $\text{Log } A_S$, obtained by applying a noise bias correction, must be positive definite. This resulted from limiting the noise power estimate of each data channel to power less than or equal to the power of data in the signal buffer. The real part of the signal log spectrum was replaced by $E(\text{Log } A_S)$. The imaginary part of the signal log spectrum remained unchanged because no phase bias correction can be derived from noise power information.

At a seismic station, the observation of past events from most regions could be characterized by a nominal value for absorption, T/Q. Events from most regions observed at NORSAR were observed to be approximately $T/Q = 0.25$, as shown for a number of events by flat displacement spectrum near the corner frequency and roll-offs of k^{-2} or k^{-3} above the corner frequency. It is expected that events from certain localized regions associated with high heat flow could be observed to have much higher absorption factors, T/Q. Regional absorption corrections were applied to the events following the method of Strick (1970). The absorption-dispersion operator used to correct the log spectrum is as follows:

Uncorrected for absorption:

$$\text{Log } Z_S(k\Delta f) = \text{Log } A_S(k\Delta f) + i\,\phi_S(k\Delta f). \qquad \text{(II-8)}$$

Corrected for absorption:

$$\begin{aligned}\text{Log } A^*_S(k\Delta f) &= \text{Log } A_S(k\Delta f) + \pi k\Delta f\,(T/Q) \\ \phi^*_S(k\Delta f) &= \phi_S(k\Delta f) + 2k\Delta f\,(T/Q)\,\log\left(\frac{1000\,\pi}{k\Delta f}\right). \qquad \text{(II-9)}\end{aligned}$$

Before applying the absorption correction, the beamformed first difference of the phase, $\Delta\phi_S(k\Delta f)$, must be numerically integrated to compute the phase. The initial phase at $k = 0$ was taken as zero. The $\Delta\phi_S(k\Delta f)$ was exponentially tapered by w^n to statistically weight the influence of low frequency phase information and to minimize roundoff errors due to the integration. The taper of 0.96 used was determined experimentally by inspection of time traces. No significant distortion of the time trace was noted for the phase angle taper greater than 0.96. The integration process used to compute $\phi_S(k\Delta f)$ follows as:

$$\phi_S(k\Delta f) = w\,\phi_S\Big((k-1)\Delta f\Big) + \Delta\phi_S(k\Delta f)$$

$$k = 1 \cdots K \qquad \phi_S(0) = 0. \tag{II-10}$$

At this point the preceding absorption corrections are applied to the real and imaginary part of the log spectrum. The absorption-dispersion corrected log spectrum of the signal is exponentiated.

$$\begin{aligned} S(k\Delta f) &= \mathrm{Exp}\Big(\mathrm{Log}\, A^*_S(k\Delta f) + i\,\phi_S(k\Delta f)\Big) \\ &= A^*_S(k\Delta f)\,[\cos\phi_S(k\Delta f) + i\sin\phi_S(k\Delta f)]\,. \end{aligned} \tag{II-11}$$

This exponentiated spectrum is transformed to the time domain:

$$d^*(nT) = FFT^{-1}\Big(S(k\Delta f)\Big),$$

to produce the complex cepstrum beamformed seismogram.

As a result of the system response correction applied to each channel fed into the above complex beamforming process, $d^*(n\Delta T)$ represents the first derivative of the acceleration of earth ground motion.

The method for correcting time domain data for system response was to experimentally fit a physically realizable and invertible spectral operator such that the power of the operator matched the power of the

system response to an impulsive ground displacement input. The spectrum of the seismic system response, $R(Z)$, is given as follows, where $Z^{-1} = \exp(-i\, 2\pi k \Delta f\, T)$ represents the spectrum of a time delay of one point sampled every T seconds:

$$R(Z) = \underset{\text{(poles)}}{R_1(Z)} * \underset{\text{(zero's)}}{R_2(Z)}$$

$$R(Z) = \left\{ \prod_{j=1}^{3} \frac{\gamma_j}{(1 - \alpha_j Z^{-1})} \right\} \left\{ \prod_{j=1}^{3} (1 - Z^{-1}) \right\} . \qquad \text{(II-12)}$$

The values of γ_j and α_j were determined by visual curve fitting where $|R(Z)|$ fitted the measured system response to within about 10 percent in the range from 0.0 Hz to 5.0 Hz. Above 5.0 Hz an analogue Butterworth filter was cascaded into the system response. Since we could not obtain consistent specifications of the roll-off between 5.0 and 10.0 Hz, no attempt was made to correct the response in that frequency range. Note that $R(Z)$ is split into two parts: the first part, $R_1(Z)$, is the weighted cascade of 3 poles with roots $Z = \alpha_j$ and weights on the input γ_j. The second part, $R_2(Z)$, is the cube of a numerator zero factor with root $Z = 1$. The inverse of $R_1(Z)$ is stable and generally increases the S/N ratio of the seismic event. This operator was applied to each input channel was follows, where $d(nT)$ is the input with seismic response $R(Z)$, and $d'(nT)$ is the output with the response $R_2(Z)$:

$$d'(nT) = \left[d(nT) - \alpha_j\, d\left((n-1)T\right) \right] / \gamma_j \, . \qquad \text{(II-13)}$$

For $j = 1$, $\gamma_1 = 1.08$, and $\alpha_1 = 0.7778$. The output of this first stage corresponding to $j = 1$ replaces the input $d(nT)$ to form a digital cascaded filter. The two following operations are $j = 2$: $\gamma_2 = 1.39$, $\alpha_2 = 0.6243$; and $j = 3$: $\gamma_3 = 3.20$, $\alpha_3 = 0$. After inverting the poles, the remainder system response $R_2(Z) = (1 - Z^{-1})^3$ is a first difference operator cascaded three times or a

third difference operator. Thus, $R_2(Z)$ approximates digitally the third derivative of ground motion displacement or first derivative of ground motion acceleration. Since $Z^{-1} = \exp(-i\ 2\pi k \Delta f\ T)$, when $k = 0$ (zero frequency), the magnification of $(1 - Z^{-1})^{-1}$ is infinite. For this reason, the inverse is taken approximately to avoid blowing up low frequency noise as:

$$\text{For acceleration:}\quad A(Z) = \frac{1 - aZ^{-1}}{1 - u_1 Z^{-1}}$$

$$\text{For velocity:}\quad V(Z) = \frac{1 - aZ^{-1}}{1 - v_1 Z^{-1}} \cdot \frac{1 - a\ Z^{-1}}{1 - v_2 Z^{-1}}$$

$$\text{For displacement:}\quad D(Z) = \frac{1 - aZ^{-1}}{1 - w_1 Z^{-1}} \cdot \frac{1 - aZ^{-1}}{1 - w_2 Z^{-1}} \cdot \frac{1 - aZ^{-1}}{1 - w_3 Z^{-1}}. \qquad \text{(II-14)}$$

The numbers used in the above spectral operators were $a = 0.98$, $u_1 = 0.9$, $v_1 = 0.91$, $v_2 = 0.90$, $w_1 = 0.92$, $w_2 = 0.91$, and $w_3 = 0.90$.

The time domain inverse operators are applied to compute the acceleration, velocity, and displacement time traces. The time domain inverse of the zeros of the system response are cascaded by the denominator of the above expressions to produce acceleration, velocity, and displacement wavelets, valid between 0.25 and 5.0 Hz. Inbetween each stage, a shortpass cepstrum filter is applied to improve the statistical estimation of the seismic ground motion and to remove time terms longer than 3.2 seconds.

The smoothing operator, which is also a short pass cepstrum operator, was performed by forming a running average of the log spectrum. The method used to average was to use staged smoothing with binomial coefficients. The smoothed log amplitude follows as:

$$\text{Log } A''_S(k\Delta f) = 0.25\Big[2 \text{ Log } A_S(k\Delta f) + \text{Log } A_S\Big((k-j)\Delta f\Big)$$

$$+ \text{ Log } A_S\Big((k+j)\Delta f\Big)\Big]$$

$$\phi''_S(k\Delta f) = 0.25\Big[2\,\phi_S(k\Delta f) + \phi_S\Big((k-j)\Delta f\Big)$$

$$+ \phi_S\Big((k+j)\Delta f\Big)\Big]. \qquad \text{(II-15)}$$

where the prime indicates the state of the data before smoothing; unprimed indicates the state after one stage of smoothing. By cascading the above operator and skipping [0, 1, 2...] points after each stage of smoothing, a Bartlett window is generated to smooth the log-spectrum. For example, after 1 stage the window weights are (1, 2, 1)/4; after 2 stages (1, 2, 3, 2, 1)/9; etc. The taper of the complex cepstrum (short pass operator) for the Bartlett window produced by I stages of smoothing is:

$$\prod_{i=1}^{I} \cos^2 i \frac{\pi}{2} \frac{n}{N} \qquad \text{(II-16)}$$

where n is the number of point delay of the complex cepstrum and N is the number of data points. It is desirable that the cepstrum taper be relatively flat up to at least 32 points delay (sampled at 0.05 seconds). To insure this condition, the output data was exponentially tapered; the velocity ground motion, exp (n/0.99); displacement ground motion, exp(n/0.98). The resultant attenuation of an M point delay operator (Z^{-M}) by smoothing and compensating with the exponential taper is shown in the following Table II-2.

The wavelets at delays less than the 32-point delay shown in the table are progressively closer to one as zero point delay is approached. It appears from these values that the displacement wavelet echoes can be

TABLE II-2

DISTORTION FIGURES DUE TO SMOOTHING THE LOG-SPECTRUM WITH A BARTLETT WINDOW

M =	32	64	80	128	Number of Smoothing Stages	Exponential Taper
Acceleration	0.98	0.92	0.88	0.72	4	1, 1, . . .
Velocity	1.22	1.14	1.00	0.42	8	Exp(0.99 n)
Displacement	1.51	1.41	1.09	0.19	12	Exp(0.98 n)

sized with reasonable accuracy up to about 4.0 seconds. This should be adequate for interpreting pP delays of explosions. For much longer delays, for example, due to multiple explosions, it may be necessary to use the acceleration or the velocity ground motion wavelet instead of the displacement wavelet. The Bartlett window used to smooth the above wavelets was determined experimentally as a requirement for containing the dominance of long-period peaks in the data, possibly due to noise. The effect of the smoothing is to statistically average out such long-period peaks over a broader band of frequencies.

2. Interactive Data Processing

a. Data Conditioning

In this phase of data processing (see Figure II-8), a seismic analyst scans a list of events and selects one for discrimination analysis. The wavelet is automatically corrected for absorption based on the parameter T/Q. The start time of the wavelet is picked. Offset of the initial point is automatically corrected. A taper is applied to avoid hard truncation of the data. The analyst is guided by displays of the wavelet and the real cepstrum of the wavelet.

The ABSORB algorithm corrects for values of T/Q using the prior described Strick model. The LOGFFT algorithm is as follows:

X_1 contains 128 points of data,

X_2 contains 128 points of log spectrum in multiplexed FFT format with imaginary part set equal to zero,

$\text{Log}\left\{FFT(X_1)\right\} \rightarrow X_2,$ $\qquad R_e()$: real part of,

$FFT^{-1}\left\{R_e(X_2)\right\} \rightarrow Y_1,$ $\qquad$ DISPLAY (X_1, Y_1).

After examining the display for the desired start point of the signal, the analyst pushes the start time button and enters the number of points delay to start the wavelet. Any initial offset due to noise is automatically removed.

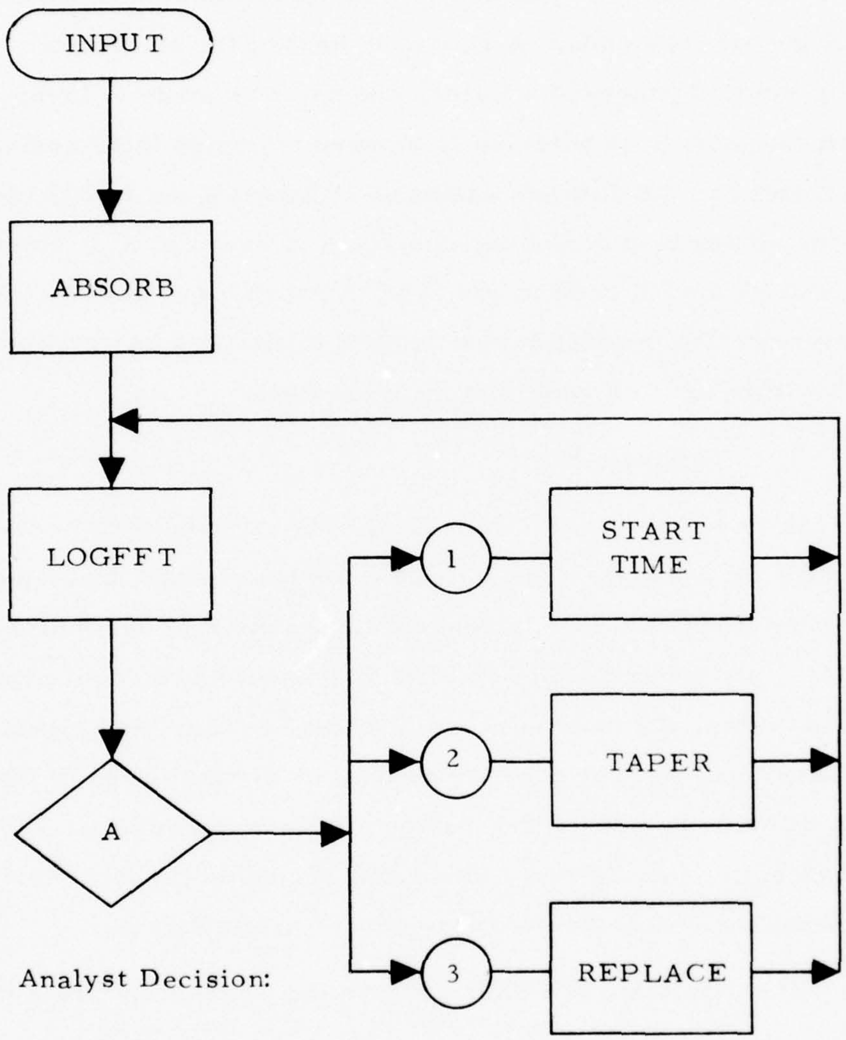


FIGURE II-8

DATA CONDITIONING

$$X(I) = X(I) - X(1) * (N - I + 1)/(N - 1). \qquad \text{(II-17)}$$

N is automatically taken as 64 with all subsequent operations being performed on 64 data points. If desired, the analyst may taper the data to remove abrupt truncations of the signal's coda. A record is kept of the number of times that the data is exponentially tapered. Later, provision is made to invert the taper and use cepstrum short pass filtering to remove unwanted later arrivals of energy. Upon exiting, the data are extended with zero's out to 128 points; and the real and imaginary part of the log-spectrum is saved in X_2. From this point on, X_2 will be stored on disc and used in passing the wavelet through to the next subroutine. The replace button is used to recover an erroneous start time or taper within the data conditioning subroutine.

b. Separate Echo

In this phase (see Figure II-9), the selected data is deconvolved to remove the apparent echo which the analyst detects by inspection of the real cepstrum display. This is done by trial-and-error input of a reflection coefficient, scattering coefficient, and the time delay in data points. By pressing a load button, the echo is held while the first arriving signal log-spectrum is smoothed to short pass the signal. A second press of the load button passes through the echo which can be similarly smoothed. A third pass of the load button reconstructs the signal by adding the first arriving signal to the echo for visual comparison with the original data.

The algorithm IFTEXP displays the wavelet and the real cepstrum.

$$FFT^{-1} \{Exp (X_2)\} \longrightarrow X_1$$

$$FFT^{-1} \{R_e (X_2)\} \longrightarrow Y_4$$

$$DISPLAY (X_1, Y_4) \quad .$$

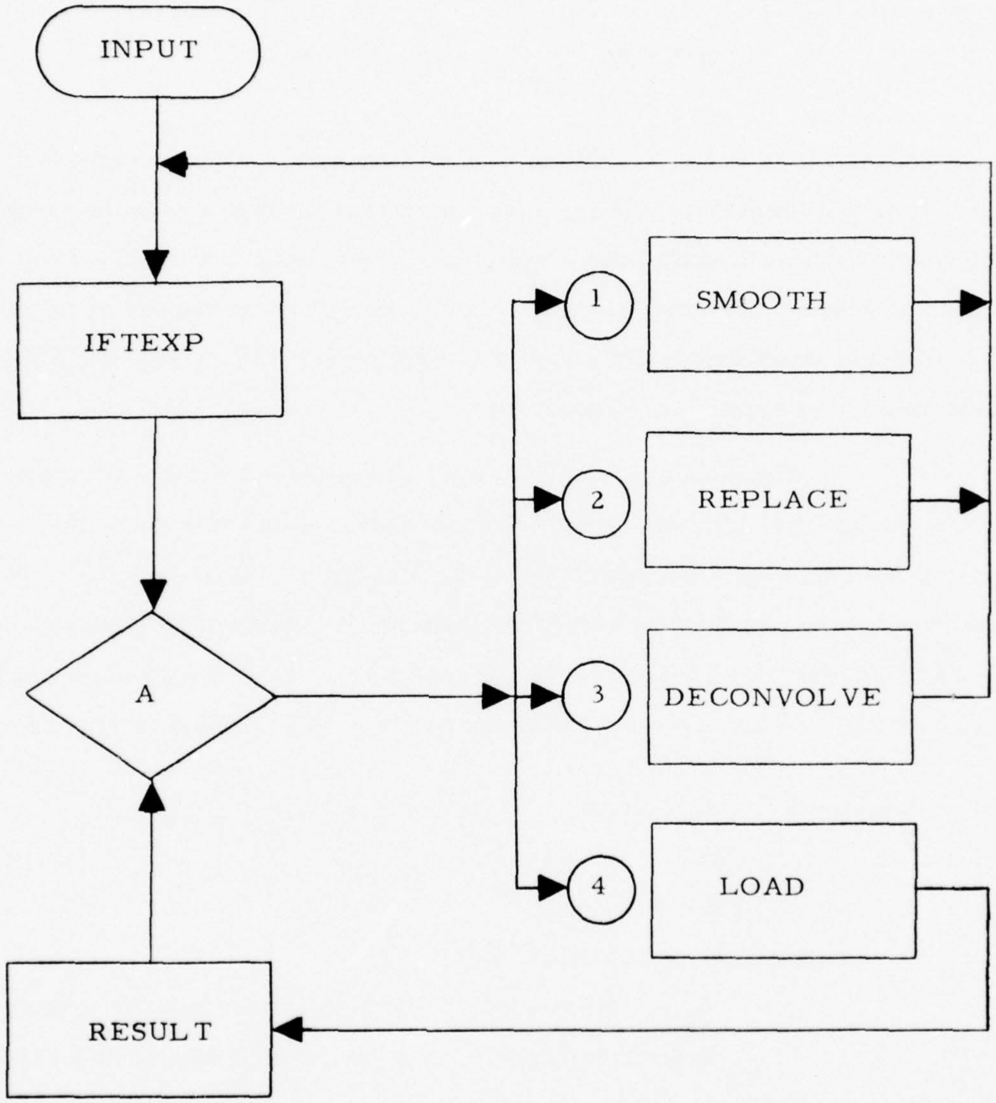


FIGURE II-9
SEPARATE ECHO

The first button pushed is DECONVOLVE which follows: Let y_i be the first arrival signal and x_i the input data:

$$y_i = a_1 y_{i-M-1} + a_2 y_{i-M} + a_1 y_{i-M+1} + x_i \qquad \text{(II-18)}$$

where

$$a_1 = RC * SC; \quad a_2 = RC * (1 - 2*SC) .$$

SC is between 0.0 and 0.5. Given 0.0 an impulsive echo is removed by the algorithm. Given other values, a symmetrical multiple echo is removed. Such an effect would shape the cepstrum trough, e.g., a double echo or smoothed echo. The analyst can try any desired combination of delay time, M; reflection coefficient, RC; and scattering coefficient, SC, until the cepstrum trough is apparently removed.

The load algorithm stacks the data and echo while the analyst smoothes the first arrival signal; and similarly smoothes the echo. After leaving the deconvolution algorithm, the flag IK is set at -1. If IK > -1, the deconvolve algorithm is an automatic return to avoid analyst error. After exiting DECONVOLVE the data are stored on Z4, and the deconvolved signal is stored on X_1, and its log-spectrum on X_2. Then LOAD is entered:

LOAD: If IK>2, return

IL = 0

IK = IK + 1

If IK ≠ 2 branch to (4)

$Z_4 + X_1 \longrightarrow Z_1$ (Reconstruct data by adding the

branch to (2). shortpassed signal and echo.)

(4) If IK = 1 branch to (1)

$Z_4 - X_1 \longrightarrow Z_1$ (echo is data minus signal)

Log $\{FFT(Z_1)\} \longrightarrow Z_2$ (return)

(3) $Z_2 \longrightarrow Z_1$

(2) $Z_3 \rightarrow Z_2$ (Data in Z_2)

$IL = IL + 1$

(1) $Z_2 \rightarrow X_2$

$Z_4 \rightarrow Z_3$

$X_1 \rightarrow Z_4$

$Z_1 \rightarrow X_1$

IF (IL. EQ. 1) Go to 3 (return) .

This LOAD algorithm automatically saves the data, deconvolved signal, and echo as they are generated and orders the data as follows: After first press of the LOAD button:

IK = 0 Z_1: original data minus deconvolved signal (raw echo)

Z_2: log spectrum of Z_1

Z_4: original data

X_1: deconvolved signal

X_2: log-spectrum of deconvolved signal

DISPLAY (Z_4, X_1, Z_1)

IK = 1 X_2: log-spectrum of raw echo

Z_3: original data

Z_4: smoothed deconvolved signal

X_1: echo

DISPLAY (Z_3, Z_4, X_1)

IK = 2 Z_1: original data

Z_2: deconvolved signal

Z_3: echo

Z_4: deconvolved signal and echo

X_1: original data

DISPLAY (Z_1, Z_2, Z_3, Z_4).

When IK = 0, the deconvolved signal is smoothed to reduce reverberation errors and short pass the signal estimate. When IK = 1, the echo estimate is similarly smoothed. When IK = 2, the smoothed signal and echo are added to reconstruct the first phase and its echo. Also, the original data are stored on X_1 to prepare input to the next subroutine which computes the residual.

c. Computation of the Residual Seismogram to Detect Multiple Events

The signal and echo of the first phase are combined to model the first arrival. This is subtracted from the original data. Any residual later phase left on the record can be picked by the analyst for possible subsequent analysis. The ratio of the removed first arrival signal to the residual is calculated from zero up to the start time picked for the possible later phase. This S/N ratio is displayed along with the possible later phase and its cepstrum. Also, here, the correlation between the signal and echo of the first phase is computed. If desired, the later phase can be stored on the disc for the next entry into SPEED and thus be analyzed as a later phase of the same event.

d. Invert Exponential Taper from the Signal Estimate

The deconvolved signal estimate is corrected for the exponential taper applied to the data in the data conditioning described in subsection a. This involves pressing the inverse exponential taper button until the number of tapers applied to the data are worked off. If roundoff errors blow up the data at long time delays, the analyst presses the zero button, inputting the number of points delay, after which the data are zeroed out to eliminate the largest roundoff errors. During the sequential inversion of the exponential taper, apparent coda noise may emerge in the tail of the signal. This can be removed by pressing the smooth button. A replace button is also available to recover from any single excessive push of any of the preceding buttons. After each

press of a button, the current state of the deconvolved signal and its cepstrum are displayed to control the next button push.

e. Absorption and Variable Frequency Magnitude Measurement

The variable frequency magnitude method of discriminating earthquakes and explosions is based on magnitude measurement at low frequency and high frequency. Explosions should be characterized by significantly lower magnitude at low frequency and higher magnitude at high frequency. First, the analyst is asked to select a low frequency, mid-band of frequencies, and high frequencies. After selecting or approving the pre-selected values, the log-amplitude versus frequency spectrum is displayed. An option is provided for picking any two frequency points and linearly extrapolating the spectrum either to the selected high or low frequency. This option is used on events only if the selected high or low frequency magnitude appears to be dominated by noise. A compute magnitude button returns a table showing the average mid-band log-amplitude, the difference between the low frequency magnitude and mid-band magnitude, and the difference between the high frequency magnitude and mid-band magnitude. Since the mid-band frequencies were selected to cover the expected peak frequency of seismometer records, the low and high frequency magnitude measurements can be approximated as the network averaged magnitude of the event as seen through the system response plus the difference magnitude at the high and low frequency, respectively.

Another processing option can be performed on the semi-log spectrum display by pressing a button for determining an absorption correction, T/Q. The amplitude spectrum of a signal with absorption is as follows:

$$Y(k\Delta f) = X(k\Delta f)\,\mathrm{Exp}(-1/2\,(T/Q)\,k\Delta f) \qquad \text{(II-19)}$$

where T is the travel time, Q is the absorption coefficient, and T/Q is approximately constant for most events. The parameter T/Q is expected to be higher than normal for certain high absorption paths. Solving the above equation for the semi-log spectrum, $\operatorname{Log} X(k\Delta f)$,

$$\operatorname{Log} X(k\Delta f) = \operatorname{Log} Y(k\Delta f) + 1/2(T/Q)k\Delta f . \qquad \text{(II-20)}$$

Rather than inputting T/Q,which is unknown, the analyst specifies whether T/Q is positive or negative. He then automatically receives a correction for T/Q = S, which produces a small rotation of the spectrum which is displayed for the analyst. After K pushes of the T/Q button, the analyst may observe that part of the spectrum is nearly flat and therefore the absorption correction is completed. At this point, the analyst exits or selects another option such as measure magnitudes, and the value of the T/Q correction is held as annotation. Entry back into condition data automatically corrects the data for absorption, and reduces the annotated T/Q back to zero. Multiple entries into condition data are taken into account in this way. In addition, the cumulative T/Q correction of the basic data is also accounted for in the annotation.

f. Corner Frequency Measurement

The semi-log spectrum display of the preceding module, corrected for absorption, is converted to a log-amplitude versus log-frequency display in this module. By picking by means of a cursor two frequencies to the left of a corner frequency and two frequencies to the right of a corner frequency, the intersection of the straight lines corresponding with each pair of points yields the corner frequency, log-amplitude of the corner frequency, and roll-off to the left and right of the corner frequencies. Up to four corner frequencies per phase can be computed in this way. Upon exiting this module, a table of corner frequencies, log-amplitudes, and roll-offs are displayed.

F. EXAMPLES OF HARDCOPY FROM SPEED

The Interactive Seismic Processing System (ISPS) provides an option to hardcopy intermediate results of processing. For the case of the SPEED module, some selected hardcopy is described and shown in Figure II-10, pages 1 through 11.

On page 1 of Figure II-10, the first time trace is a presumed explosion from Kazakh corrected for instrument response to approximate ground displacement from 0.3 to 5.0 Hz. The second time trace is the positive half real cepstrum obtained by transforming the log-amplitude spectrum into the time domain. Each hashmark on the cepstrum trace represents a delay of four points. A possible echo appears to be indicated on the seventh point. The top annotation indicates the event number, source location and origin time, magnitude, depth, station, channel and component number, station coordinates, arrival time, event azimuth and distance, and sample period. The second annotation line indicates that the event was exponentially tapered twice, started on the first point of input data, and the event amplitude. The last line of annotation labels the real cepstrum of the first phase picked and indicates the maximum amplitude of the trace.

On page 2 of Figure II-10, the first trace shows the displacement wavelet, the second trace shows the displacement wavelet with the pP echo apparently removed, and the third trace shows the echo. The peak amplitude of the deconvolved displacement wavelet is increased as expected, and one-sided as expected.

On page 3 of Figure II-10, the deconvolved wavelet and its cepstrum are shown. The second line of annotation shows the reflection coefficients of the pP echo, the scattering coefficient used to shape the echo, number of points delay, and amplitude.

On page 4, the deconvolved displacement wavelet was smoothed in the log-spectrum domain with a Bartlett window of five points (triangular half-width). This short passes the displacement wavelet as shown on trace 1. The cepstrum of the short passed displacement wavelet is shown on trace 2.

On page 5, the first time trace shows the displacement wavelet. The second time trace, the short passed deconvolved displacement wavelet. The third trace, the short passed echo. The fourth, the displacement data reconstructed by adding the short passed deconvolved wavelet to the short passed echo. Comparison of the reconstructed data and original data shows close correspondence. The amplitude of the reconstructed wavelet is down 50 nm or about 1% from the original data.

On page 6 of Figure II-10, the difference between the original data and reconstructed data is shown on trace 1. The maximum difference is 658 nm or about 12% of the maximum signal amplitude. The largest errors occur before the start of the signal, under the echo, and at the end of the data trace. Under the first arrival pulse, the error is much less, several percent. The second trace shows the cepstrum of the residual trace. The last line of annotation shows the correlation coefficient between the signal and echo as -0.988.

On page 7, the result of using a cursor to pick a possible later phase is shown. The first trace shows the later phase, the second, its cepstrum. The second line of annotation indicates that the later phase was time delayed 41 points and its maximum amplitude is 514 nm. The bottom line of annotation indicates a signal to noise ratio of 12.4 db based on power of the data compared to the power of the residual trace obtained by removal of the reconstructed data, computed up to the presumed arrival of the later phase. The so-called later phase was picked for demonstration purpose and is not considered a valid later phase.

On page 8 of Figure II-10, the short passed deconvolved wavelet is shown with the applied exponential taper inverted. The amplitude of the signal was increased from 4,560 nm to 6,420 nm. This is the best measurement of signal amplitude. The cepstrum is shown on the second trace. Small positive secondary delays are indicated with 4-point and 7-point delays. These can be seen on trace 1, the displacement first arrival wavelet, as possible small secondary arrivals as peaks with 4-point and 7-point delays, consistent with the cepstrum.

On page 9, the log-amplitude spectrum is plotted as a function of frequency. The vertical lines show on the left the low frequency used to compute low frequency magnitude. The two middle lines show the two frequencies for averaging mid-band magnitude. The right vertical line shows the frequency used to compute high frequency magnitude. The T/Q factor of zero indicates no absorption correction was applied to the input data. The bottom line shows smoothes equal to zero, indicating that the log-amplitude was not smoothed. The log-amplitude of 2.92 - 4.47 shows the range of log-amplitude in the plot, with base 10 logarithms.

On page 10, the semi-logarithm spectrum of the first arriving signal pulse is shown corrected for absorption using a T/Q equal to 0.225. The log-amplitude range has, of course, been narrowed by the absorption corretion from 4.00 to 4.50. The absorption correction will, as expected, significantly increase the magnitude of the event. The average log-amplitude between 1.00 and 1.75 Hz is 4.37. The difference log-amplitude at 0.3 Hz is 0.13 magnitude units. The difference log-amplitude at 2.50 Hz is -0.03 magnitude units.

On page 11, the log-amplitude spectrum of the deconvolved displacement wavelet is plotted against the log-frequency from 0.45 Hz to 3.5 Hz. This plot includes the previous correction for absorption. The integers 1 and 2 next to the plot indicate where corner frequencies were picked. The

log-frequency from -0.35 to 0.55 indicates the log-frequency range of the horizontal axis,and the specification amplitude from 3.98 to 4.48 indicates the range of log-amplitudes on the vertical axis. The last four lines of annotation provides a table of corner frequency information. The corner frequencies for pick 1 and pick 2 are given under column 1 and column 2, respectively, in log base ten units. The magnitude at the corner frequencies is also given in log base ten units. The left slope indicates the power f^a roll-off to the left of the corner frequency pick. The right slope, to the right of the corresponding corner frequency peak. The results for this event indicated a corner frequency at 2.4 Hz nearly flat to the left of the corner with roll-off of 1.8 power to the right of the corner. Another corner was picked at 2.9 Hz with roll-off of 3.0 power to the right of that corner. Sax (1975) indicated that measurements of log-amplitude and corner frequencies could be used to discriminate between earthquakes and explosions. In that study, maximum entropy spectral estimates were used. In this study, conventional discrete Fourier transforms were linearly interpolated at uniformly coupled log-frequencies after correcting for absorption, based on the assumption that at least part of the displacement wavelet spectrum is flat.

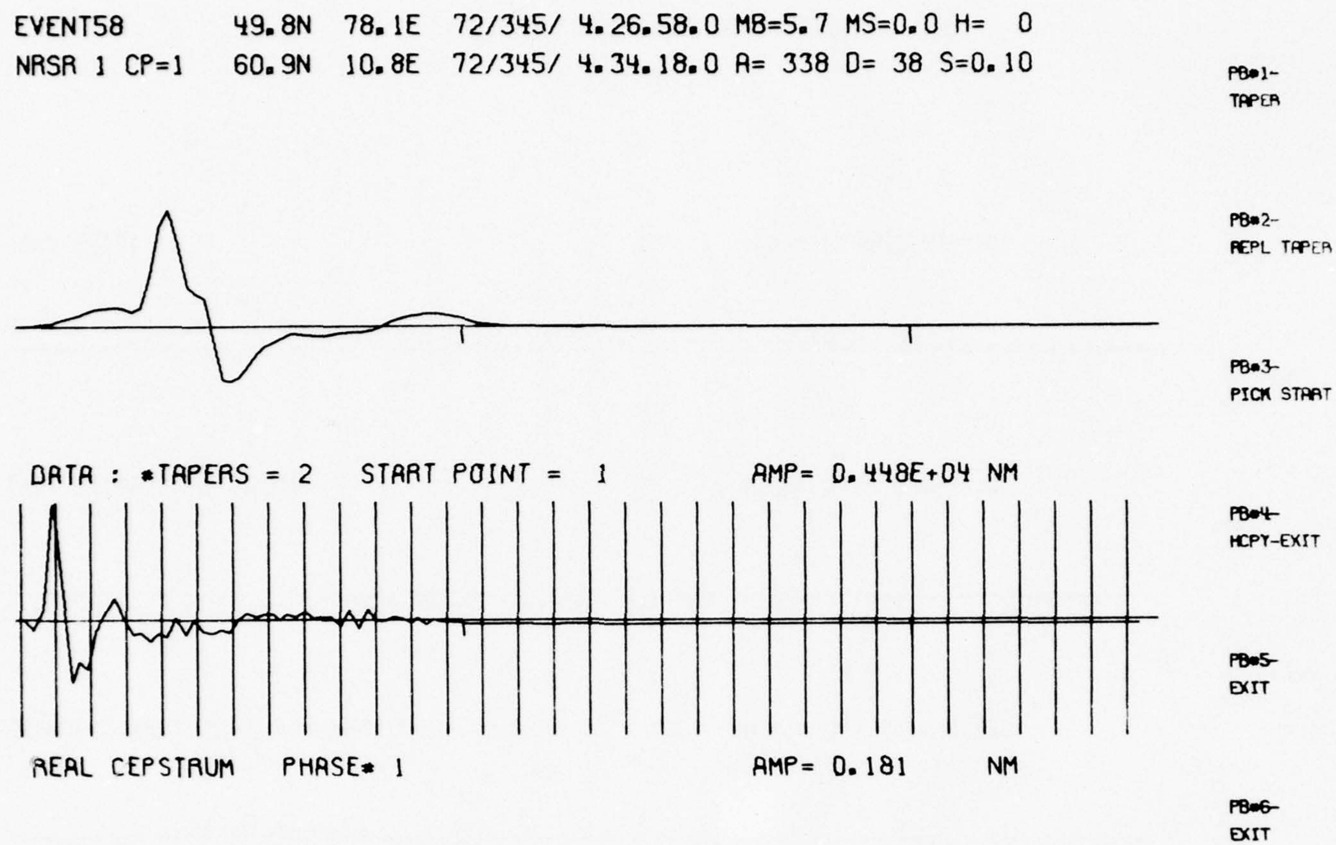


FIGURE II-10

PROCESS SPEED HARDCOPY
(PAGE 1 OF 11)

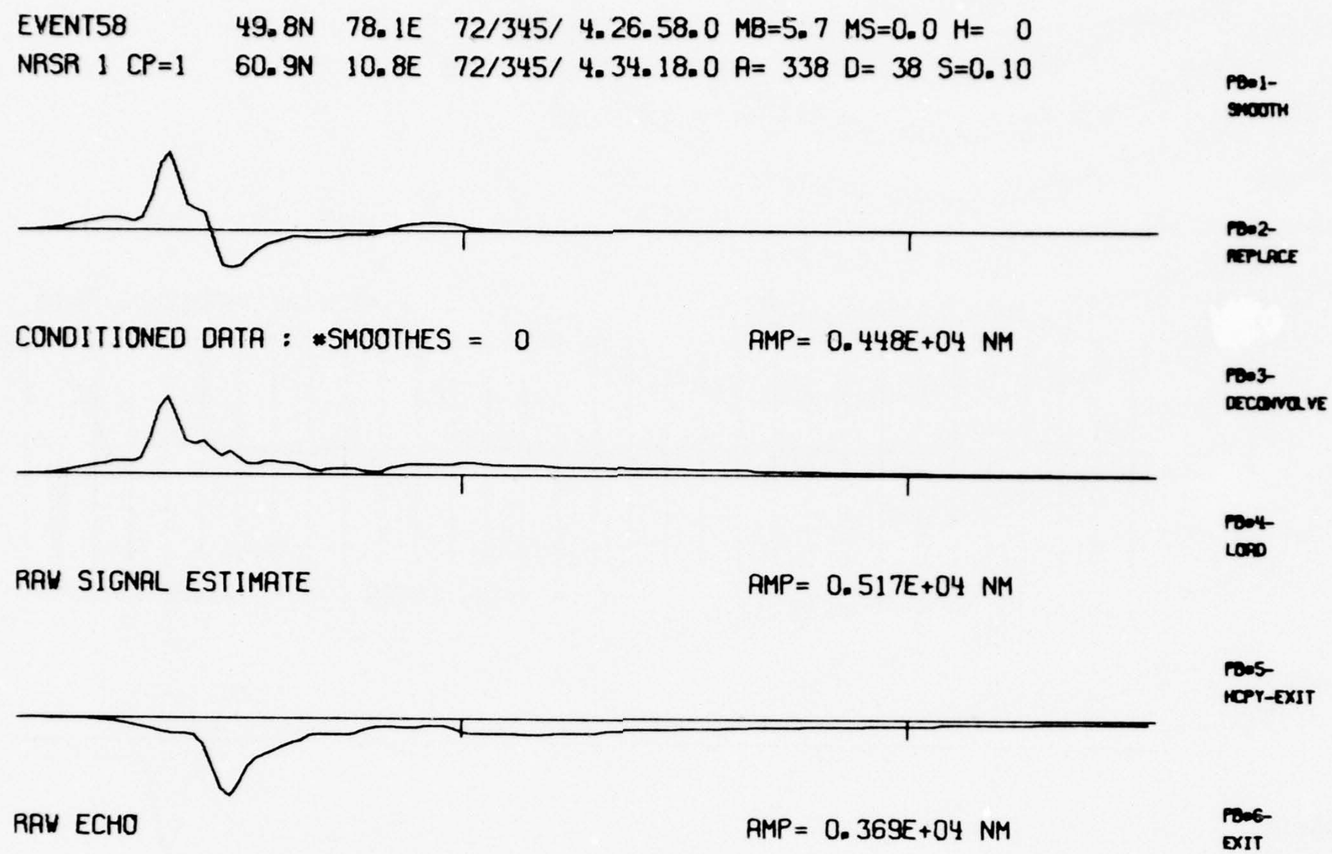


FIGURE II-10

PROCESS SPEED HARDCOPY
(PAGE 2 OF 11)

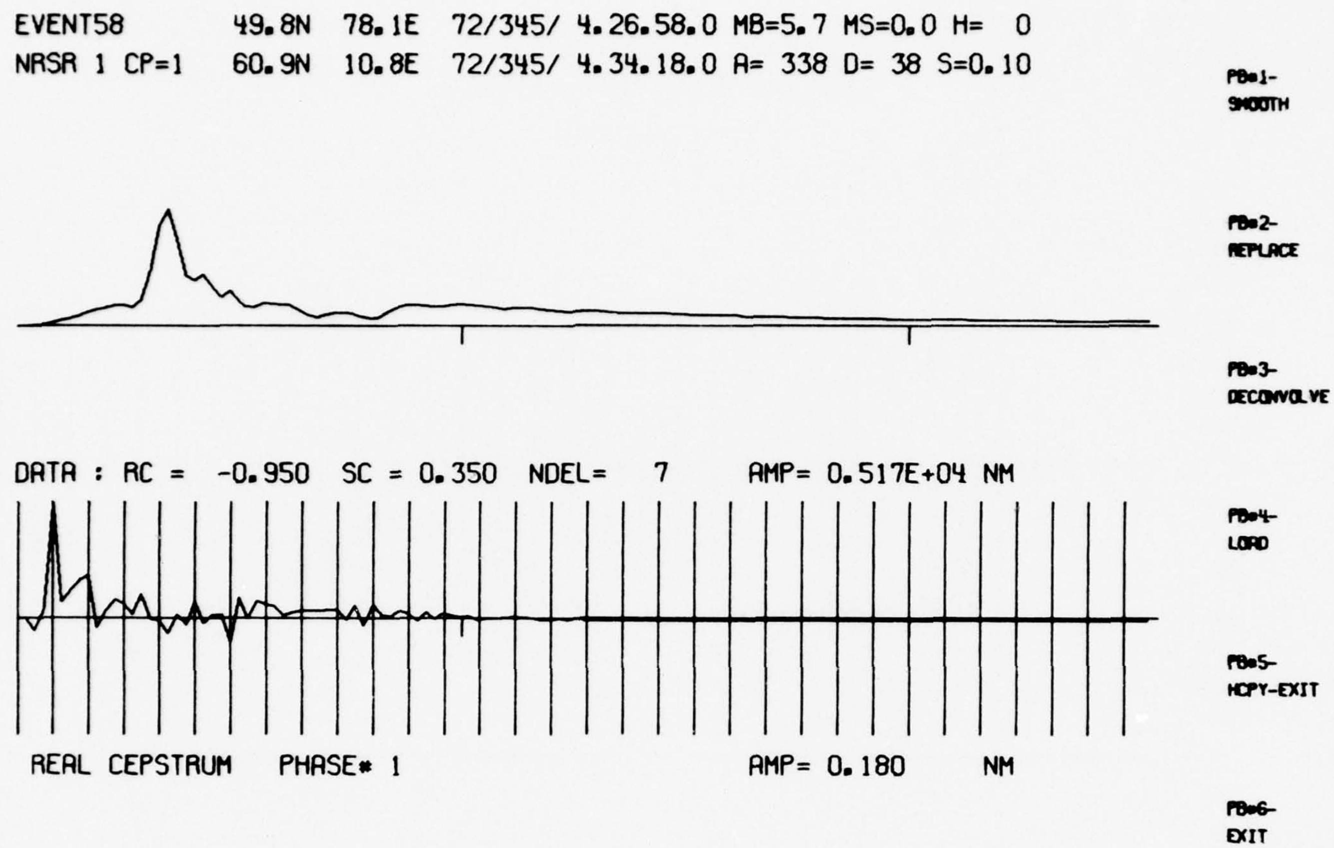


FIGURE II-10

PROCESS SPEED HARDCOPY
(PAGE 3 OF 11)

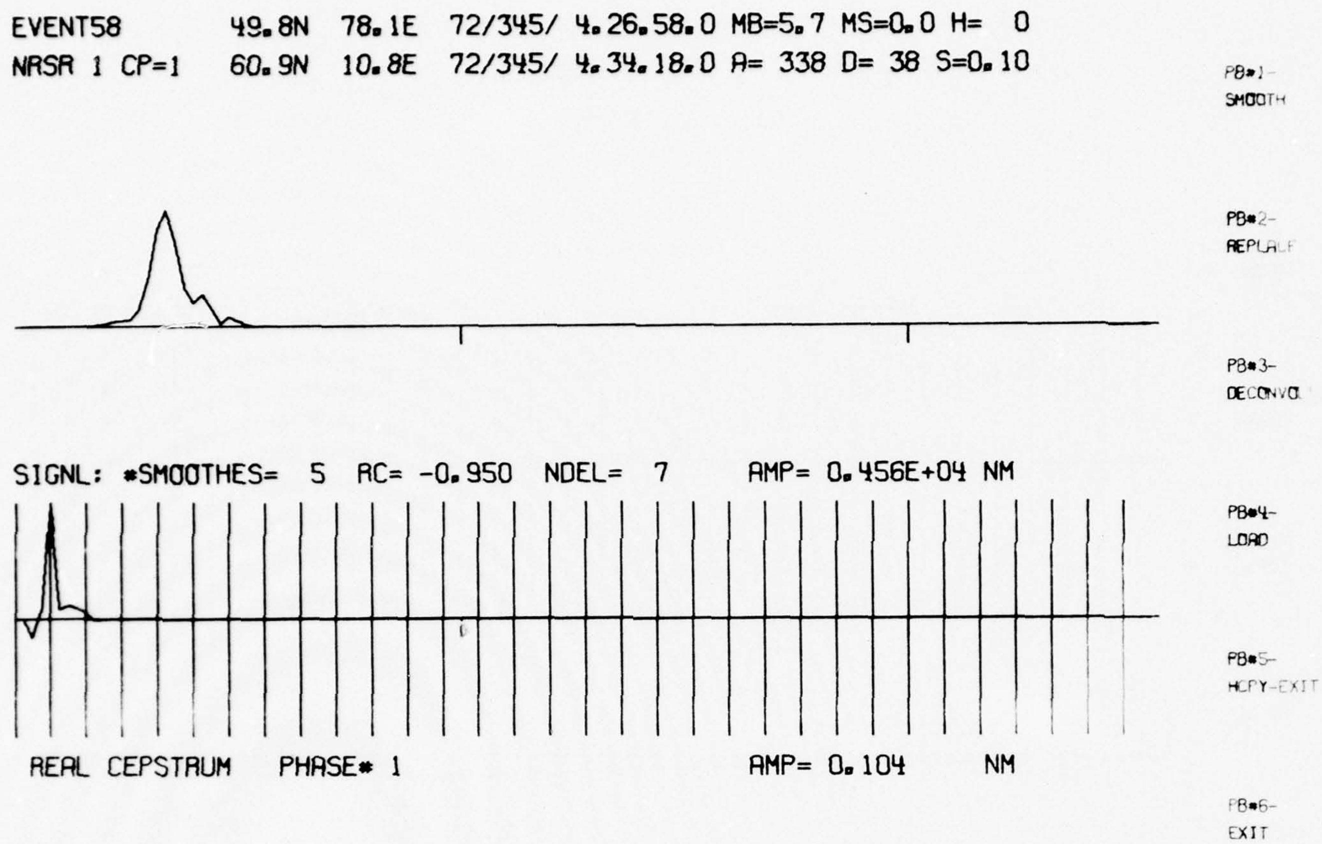


FIGURE II-10

PROCESS SPEED HARDCOPY
(PAGE 4 OF 11)

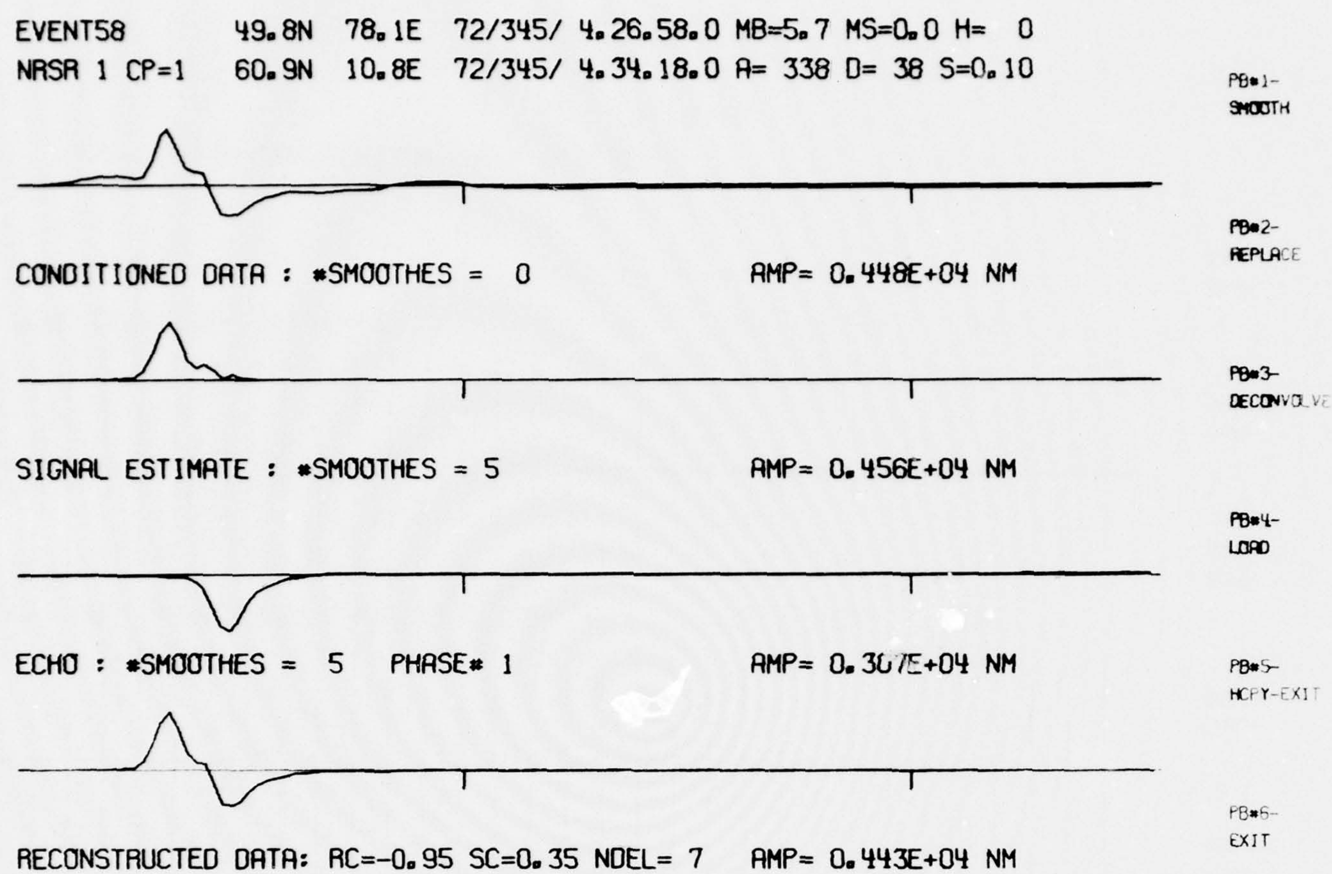
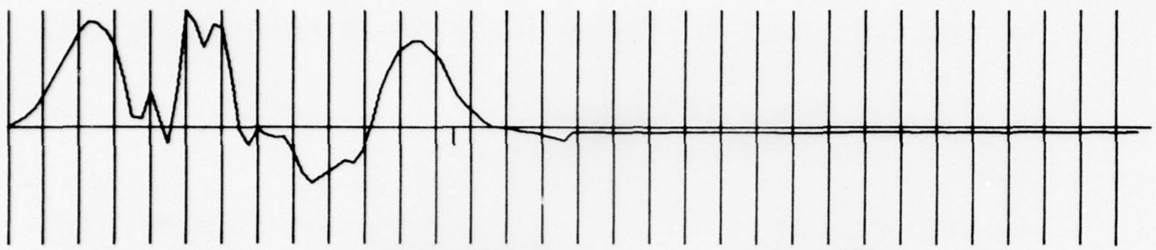


FIGURE II-10

PROCESS SPEED HARDCOPY
(PAGE 5 OF 11)

EVENT58 49.8N 78.1E 72/345/ 4.26.58.0 MB=5.7 MS=0.0 H= 0
NRSR 1 CP=1 60.9N 10.8E 72/345/ 4.34.18.0 A= 338 D= 38 S=0.10

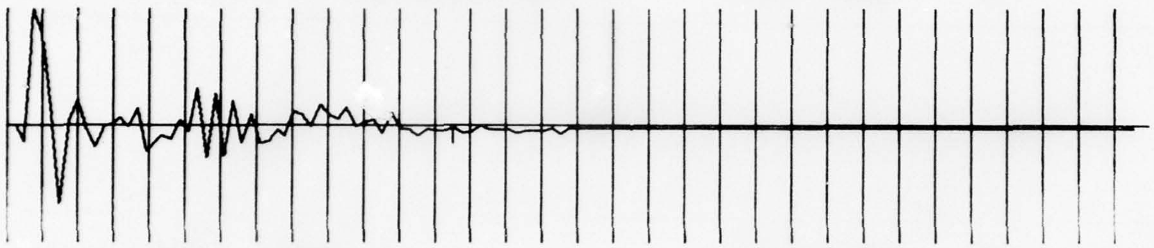
PB*1- SMOOTH



PB*2- REPLACE

PB*3- RESIDUAL

RESIDUAL: *SMOOTHES= 0 *PTS.SHIFTED= 0 AMP= 658. NM



PB*4- HCPY EXIT

PB*5- SAV PRMTRS

REAL CEPSTRUM PHASE* 2 AMP= 0.244 NM

PB*6- EXIT

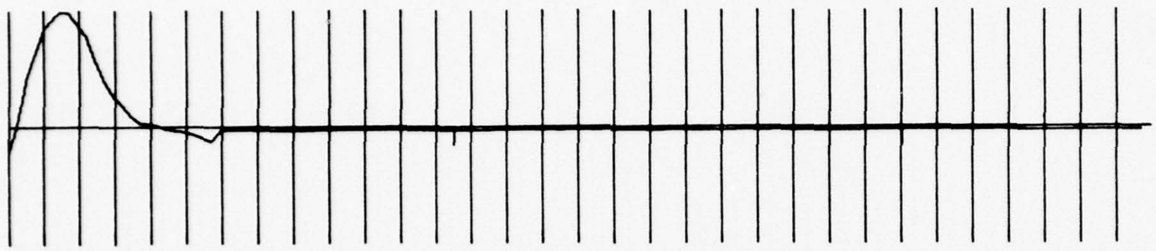
(SIGNAL,ECHO) CORRELATION COEF=-0.988E+00

FIGURE II-10

PROCESS SPEED HARDCOPY
(PAGE 6 OF 11)

EVENT58 49.8N 78.1E 72/345/ 4.26.58.0 MB=5.7 MS=0.0 H= 0
NRSR 1 CP=1 60.9N 10.8E 72/345/ 4.34.18.0 A= 338 D= 38 S=0.10

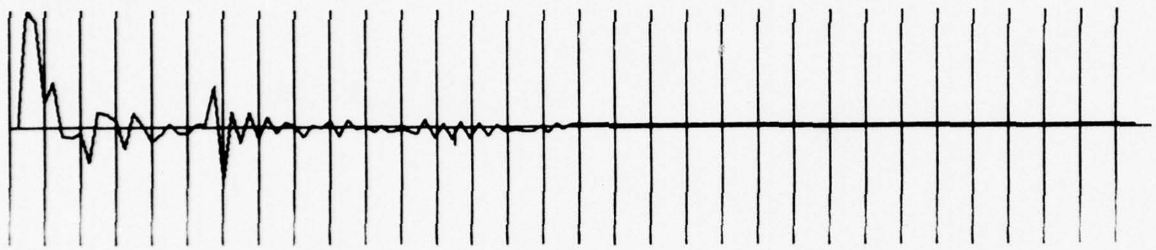
PB*1- SMOOTH



PB*2- REPLACE

PB*3- RESIDUAL

RESIDUAL: *SMOOTHES= 0 *PTS.SHIFTED= 41 AMP= 514. NM



PB*4- HCPY EXIT

PB*5- SAV PAMTRS

REAL CEPSTRUM PHASE* 2 AMP= 0.261 NM

PB*6- EXIT

(SIGNAL,ECHO) CORRELATION COEF=-0.988E+00 SNR = 0.124E+02 DB

FIGURE II-10

PROCESS SPEED HARDCOPY
(PAGE 7 OF 11)

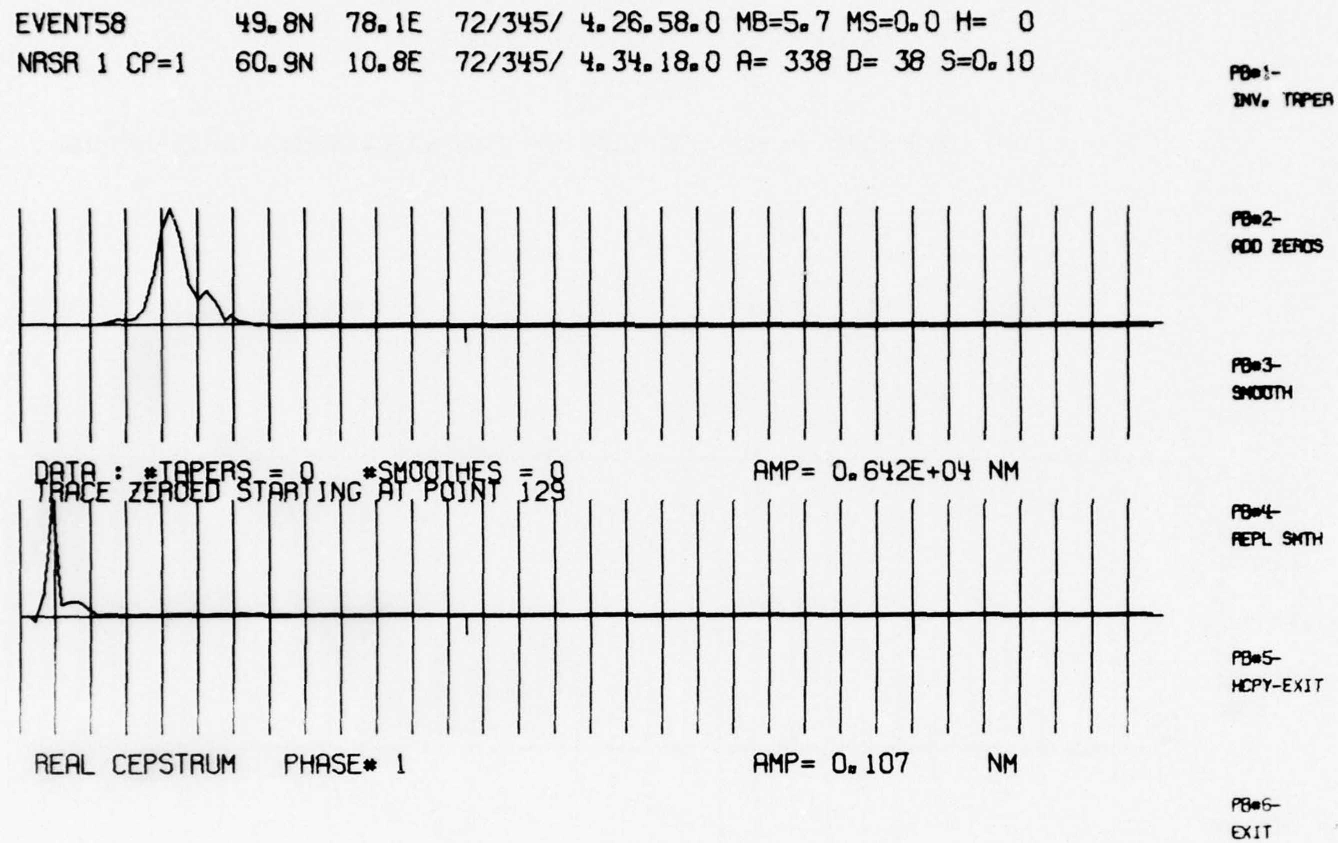


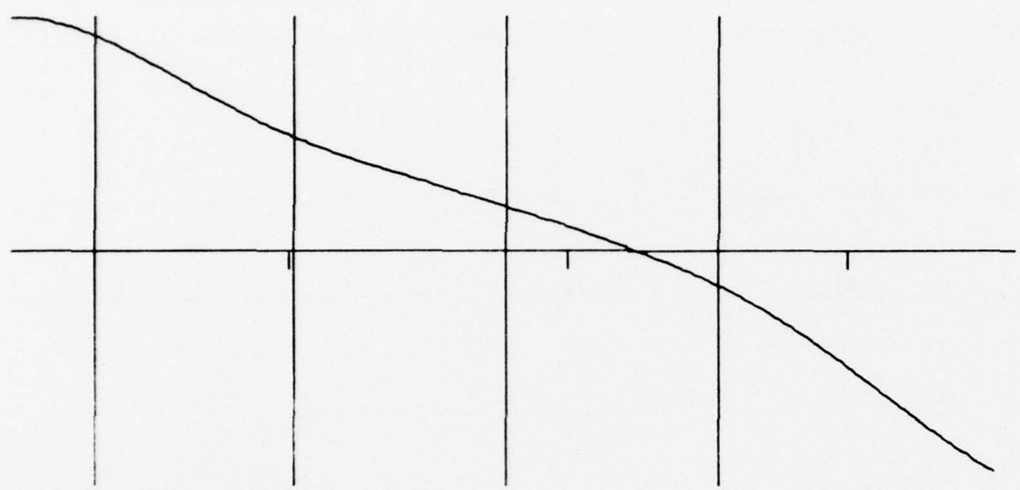
FIGURE II-10

PROCESS SPEED HARDCOPY
(PAGE 8 OF 11)

EVENT58 49.8N 78.1E 72/345/ 4.26.58.0 MB=5.7 MS=0.0 H= 0
NRSR 1 CP=1 60.9N 10.8E 72/345/ 4.34.18.0 A= 338 D= 38 S=0.10

PHASE# 1 REAL SPECTRUM BETWEEN 0.00HZ AND 3.50HZ

T/Q FACTOR IS 0.000E+00



REAL LOG SPECTRUM DATA: #SMOOTHES= 0 AMP= 2.92 - 4.47

PB#1-
SMOOTH

PB#2-
REPLACE

PB#3-
T/Q FACTOR

PB#4-
MEAS. MAG.

PB#5-
HCPY-EXIT

PB#6-
EXIT

FIGURE II-10

PROCESS SPEED HARDCOPY
(PAGE 9 OF 11)

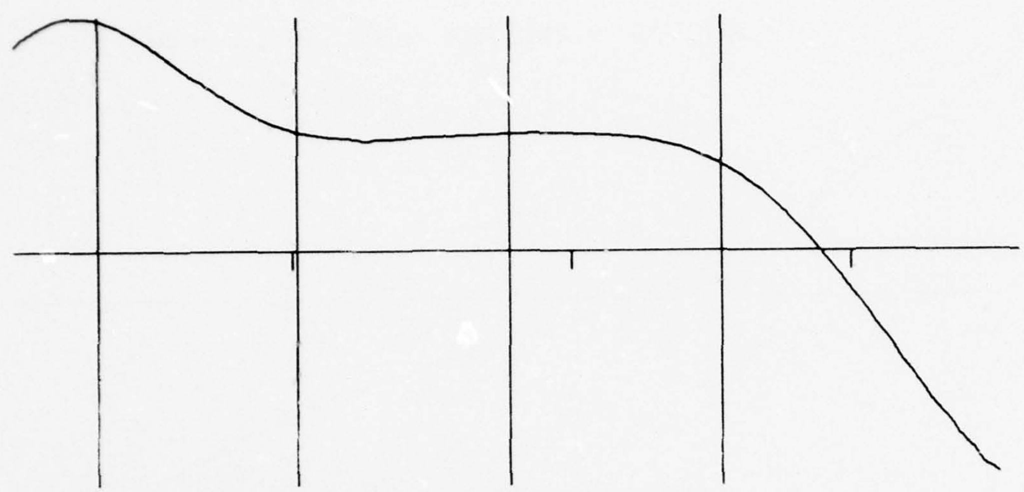
EVENT58 49.8N 78.1E 72/345/ 4.26.58.0 MB=5.7 MS=0.0 H= 0
NRSR 1 CP=1 60.9N 10.8E 72/345/ 4.34.18.0 A= 338 D= 38 S=0.10

PB#1- SMOOTH

PHASE# 1 REAL SPECTRUM BETWEEN 0.00HZ AND 3.50HZ

T/Q FACTOR IS 0.225E+00

PB#2- REPLACE



PB#3- T/Q FACTOR

PB#4- MEAS. MAG.

PB#5- HCPY-EXIT

REAL LOG SPECTRUM DATA: #SMOOTHES= 0 AMP= 4.00 - 4.50
MB AVERAGED BETWEEN 1.00 AND 1.75HZ IS 4.37
DIFFERENCE FROM AVERAGE MB EVALUATED AT 0.30HZ IS 0.13
DIFFERENCE FROM AVERAGE MB EVALUATED AT 2.50HZ IS -0.03
FREQ PICKS: 0.000 0.000 0.000 0.000

PB#6- EXIT

FIGURE II-10

PROCESS SPEED HARDCOPY
(PAGE 10 OF 11)

EVENT58 49.8N 78.1E 72/345/ 4.26.58.0 MB=5.7 MS=0.0 H= 0
NRSR 1 CP=1 60.9N 10.8E 72/345/ 4.34.18.0 A= 338 D= 38 S=0.10

PB=1- CORNER FRQ

LOG SPECTRUM VS. LOG FREQUENCY PHASE# 1

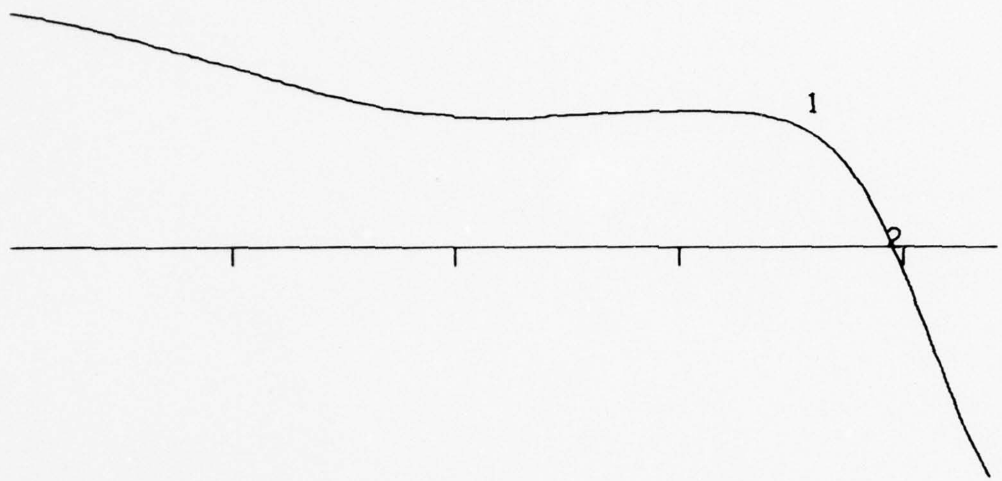
PB=2- REPL C F

PB=3- HCPY EXIT

PB=4- EXIT

PB=5- EXIT

PB=6- EXIT



LOG FREQ -0.350 - 0.550 SPEC AMP= 3.98 - 4.48

CORN FREQS	0.3852	0.4618	0.0000	0.0000
MAG AT C.F.	4.3832	4.2395	0.0000	0.0000
LEFT SLOPE	0.0510	-1.8627	0.0000	0.0000
RGHT SLOPE	-1.8627	-3.0657	0.0000	0.0000

FIGURE II-10

PROCESS SPEED HARDCOPY
(PAGE 11 OF 11)

SECTION III

EVALUATION OF ROUTINE DISCRIMINATION PROCESSING PROCEDURES

A. INTRODUCTION

In the context of a real time surveillance system environment, it is estimated that an average of fifty events per day will be collected. After each event is located, the retrieved station waveforms are time-aligned to measure accurate focal parameters and to measure accurate station parameters such as station magnitude and arrival time deviations, first motion sense, and other station parameters. The station waveforms are further reduced to one or several event waveform representations for routine discrimination processing. One of the possible reduction methods used is cepstrum beamforming, which reduces ambient and coda noise subject to the constraint that log-amplitude spectrum of the estimates source signal is the average of all the input channels fed into the cepstrum beamforming process. The algorithm used to compute the cepstrum beamforming data is described in the preceding section.

The discrimination processing performed on data collected in a real time surveillance mode must all be done with sufficient speed to keep up on an average with the event load collected by the system. This means that all routine discrimination processing must be done in less than one-half hour. This provides sufficient event processing capacity to work off backlogs due to occasional swarms of events in a reasonable span of time.

For the purpose of quickly evaluating proposed standards of short-period discrimination processing, a data base of thirty-five events was prepared. The data base consisted of twenty earthquakes and fifteen

presumed explosions. All events were selected in the teleseismic range from 25 degrees to 85 degrees epicentral distance. Two classes of earthquakes were selected. In one class labelled as simple earthquakes, the events were impulsive with the maximum peak occurring in the first several seconds. In the other, labelled as complex earthquakes, the maximum peak occurs later than the first several seconds. Earthquake events were assigned to these groupings to equally weight earthquake results for simple and complex events and, if possible, differentiate results obtained for these two groupings. The magnitudes of events selected for the data base nearly uniformly cover the range from 4.5 to 6.0 for all classes of events: simple earthquakes, complex earthquakes, and presumed explosions. All earthquakes selected were shallow focus where determined or otherwise of indicated normal depth (33 km). The presumed explosion data included twelve events from the eastern Kazakh region, including two presumed PNE's; two events from NTS; and one from Colorado. All the data used were recorded at NORSAR on twenty-two subarrays. All the data preparation and interactive processing were performed starting at the level of 132 individual sensor records and working down to the level of the several event waveform representations used for discrimination processing. The processing procedures developed, when perfected, could be adapted to processing a sizeable network of sensors within the time constraints imposed by the requirement for real time rate event classification processing.

The purpose of the data base is to provide preliminary screening of the effectiveness of discrimination methodologies which are possible candidates for routine on-line discrimination processing. Although the screening procedure should quickly eliminate discrimination procedures which perform poorly, any positive results should be further tested with a much larger data base before acceptance of the procedure is finalized. A description of the earthquake event information is shown in Table III-1; of the presumed explosion data, in Table III-2.

TABLE III-1

EARTHQUAKE DATA BASE
(PAGE 1 OF 2)

Simple Earthquakes								
Event Number	Magnitude	Depth (km)	Distance (degrees)	Azimuth	Latitude (^{o}N)	Longitude (^{o}E)	Date	Origin Time
30	4.5	27	25.1	155.4	37.1	24.0	02/13/72	13:07:10.5
06	4.6	N	32.7	116.6	38.1	49.1	05/15/71	04:53:05.5
44	4.7	N	59.4	77.1	32.6	95.8	07/16/72	03:40:00.0
48	4.8	N	56.2	162.9	56.2	162.9	07/31/72	06:40:28.0
57	4.8	N	49.5	87.3	35.8	80.6	07/24/72	15:06:19.8
31	4.9	17	44.5	83.3	41.3	79.3	07/03/71	04:33:49.1
14	5.4	16	55.4	87.7	30.8	84.5	05/03/71	00:42:13.3
04	5.6	20	65.3	23.3	50.4	156.8	08/01/71	02:16:04.1
87	5.9	28	76.0	40.0	35.0	141.2	01/20/75	17:31:10.6
21	6.1	29	65.3	35.0	46.7	141.4	09/06/71	13:37:11.0

N - Not Given.

TABLE III-1

EARTHQUAKE DATA BASE
(PAGE 2 OF 2)

Complex Earthquakes								
Event Number	Magnitude	Depth (km)	Distance (degrees)	Azimuth	Latitude (^oN)	Longitude (^oE)	Date	Origin Time
26	4.5	9	24.8	143.0	39.0	29.8	10/05/71	18:53:06.0
17	4.8	N	61.6	16.9	55.6	163.9	01/12/72	20:20:15.0
20	5.0	N	48.1	88.2	36.5	78.5	08/29/71	15:16:56.0
01	5.1	55	63.9	19.7	52.8	160.8	06/15/71	14:04:08.0
02	5.2	N	44.1	84.0	41.5	78.3	06/19/71	17:23:02.0
55	5.4	31	40.4	121.0	30.1	50.8	07/02/72	12:56:07.0
38	5.5	23	44.9	86.2	31.4	91.5	02/11/72	05:55:46.0
89	5.7	7	74.3	48.5	33.2	131.3	04/20/75	17:35:50.4
90	5.8	24	74.3	38.5	37.1	142.1	05/04/75	09:31:59.5
22	6.0	7	69.9	29.2	44.4	150.9	09/09/71	23:01:06.0

N - Not Given.

TABLE III-2

PRESUMED EXPLOSION DATA BASE

Event Number	Magnitude	Depth (km)	Distance (degrees)	Azimuth	Latitude (^{o}N)	Longitude (^{o}E)	Date	Origin Time
56	4.4	0	37.8	76.0	49.7	78.0	07/06/72	01:02:58.0
77	4.7	0	37.2	75.7	49.9	78.1	06/25/74	03:56:57.6
16	4.7	0	37.5	76.0	49.9	77.6	12/07/74	05:59:56.9
49	5.1	0	37.4	75.9	50.0	77.7	09/02/72	08:56:58.0
51	5.2	0	37.8	75.8	49.8	78.1	08/16/72	03:16:57.2
32 *	5.2	0	35.8	88.8	45.6	67.9	09/13/73	02:59:57.2
60 *	5.3	0	37.7	92.6	42.7	67.4	08/15/73	01:59:58.0
59	5.4	0	68.0	313.9	39.8	-108.4	05/17/73	16:00:00.0
7	5.4	0	38.0	74.7	50.1	79.1	06/30/71	03:56:57.2
13	5.5	0	37.4	75.9	50.0	77.7	06/06/71	04:02:57.1
15	5.5	0	73.0	318.4	37.1	-116.0	07/08/71	14:00:00.0
81	5.6	0	72.9	318.4	37.2	-116.0	07/26/74	15:05:00.2
58	5.7	0	37.8	75.8	49.8	78.1	12/10/72	04:26:57.7
11	5.8	0	72.9	318.4	37.2	-116.0	08/30/74	15:00:00.0
53	6.0	0	37.9	74.9	50.1	78.8	12/10/72	04:27:08.4

* Presumed PNE.

On Figure III-1, plots are shown of the representative event waveforms obtained by cepstrum beamforming. The waveforms are shown as seen through the system response and as corrected for ground motion (acceleration, velocity, displacement as specified by the user) in the band of frequencies between 0.25 and 5.0 Hz.

B. BASELINE FOR SHORT-PERIOD DISCRIMINATION PROCESSING

In Section II, an example of the application of short-period interactive processing was shown. In the example, it was possible with very little ambiguity to use the cepstrum to deconvolve an apparent echo to derive the expected one-sided displacement wavelet and echo with correlation coefficients close to unity. However, in attempting to repeat the performance on all the events in the screening data base, it was no longer found to be possible to consistently and unambiguously use the cepstrum to deconvolve an apparent highly correlated echo as in the example. To develop a satisfactory procedure for routine discrimination processing, a baseline procedure will be defined. The procedure will be run through the screening data base to establish performance figures for the baseline procedure. By systematically evolving procedures which can be shown to perform more effectively than the baseline procedure, a satisfactory procedure for discrimination processing can eventually be developed. The interactive SPEED program is a useful research tool for this purpose. By specifying a processing procedure, the entire screening data base can be run in two or three hours to provide basic data for preliminary evaluation of the procedure.

The procedure followed to establiah a baseline for discrimination was to measure variable frequency magnitude data on seismic data corrected for system response to ground displacement and ground acceleration. All the event data were processed as follows:

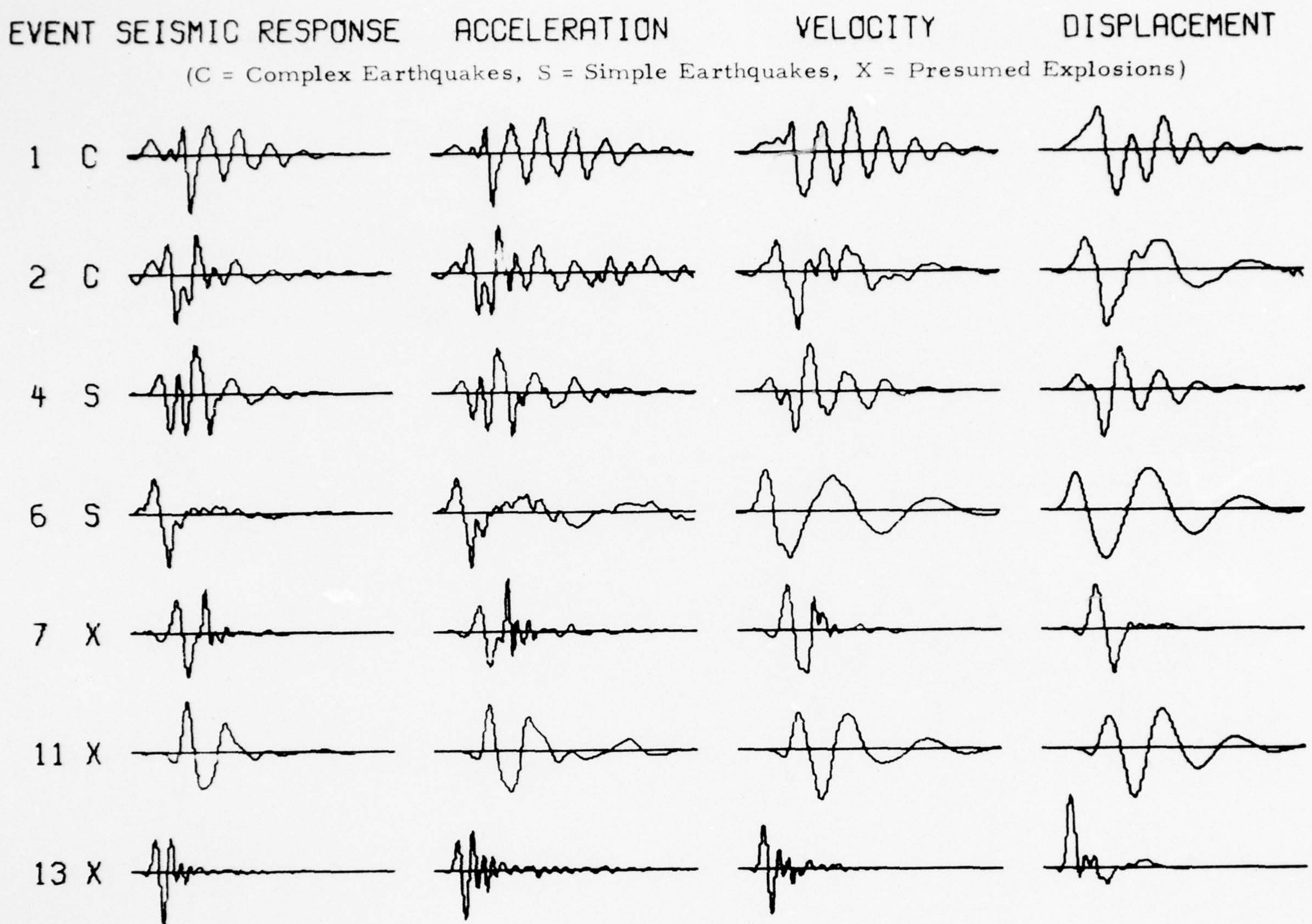


FIGURE III-1

PLOTS OF WAVEFORMS OBTAINED BY CEPSTRUM BEAMFORMING
(PAGE 1 OF 5)

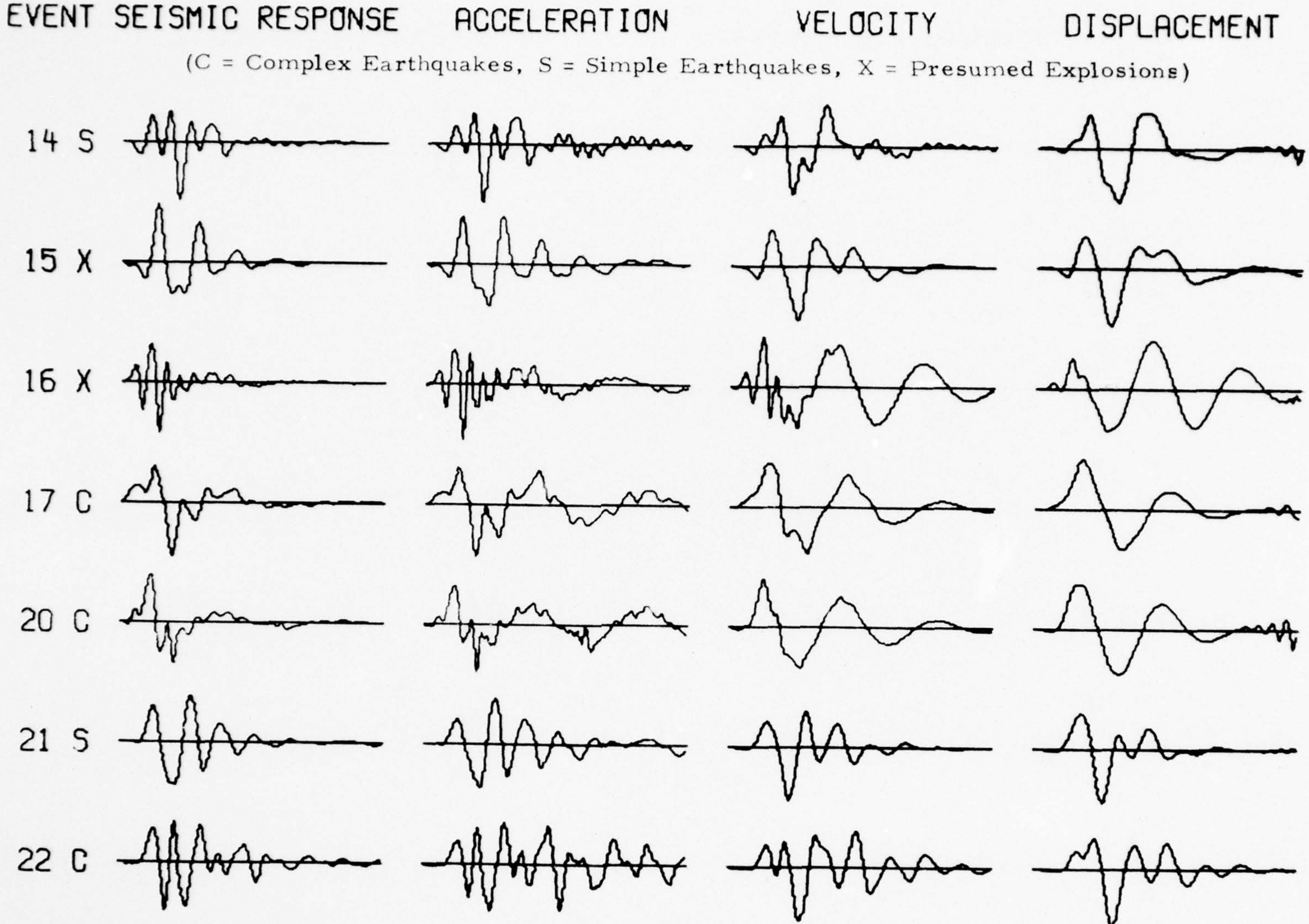


FIGURE III-1

PLOTS OF WAVEFORMS OBTAINED BY CEPSTRUM BEAMFORMING
(PAGE 2 OF 5)

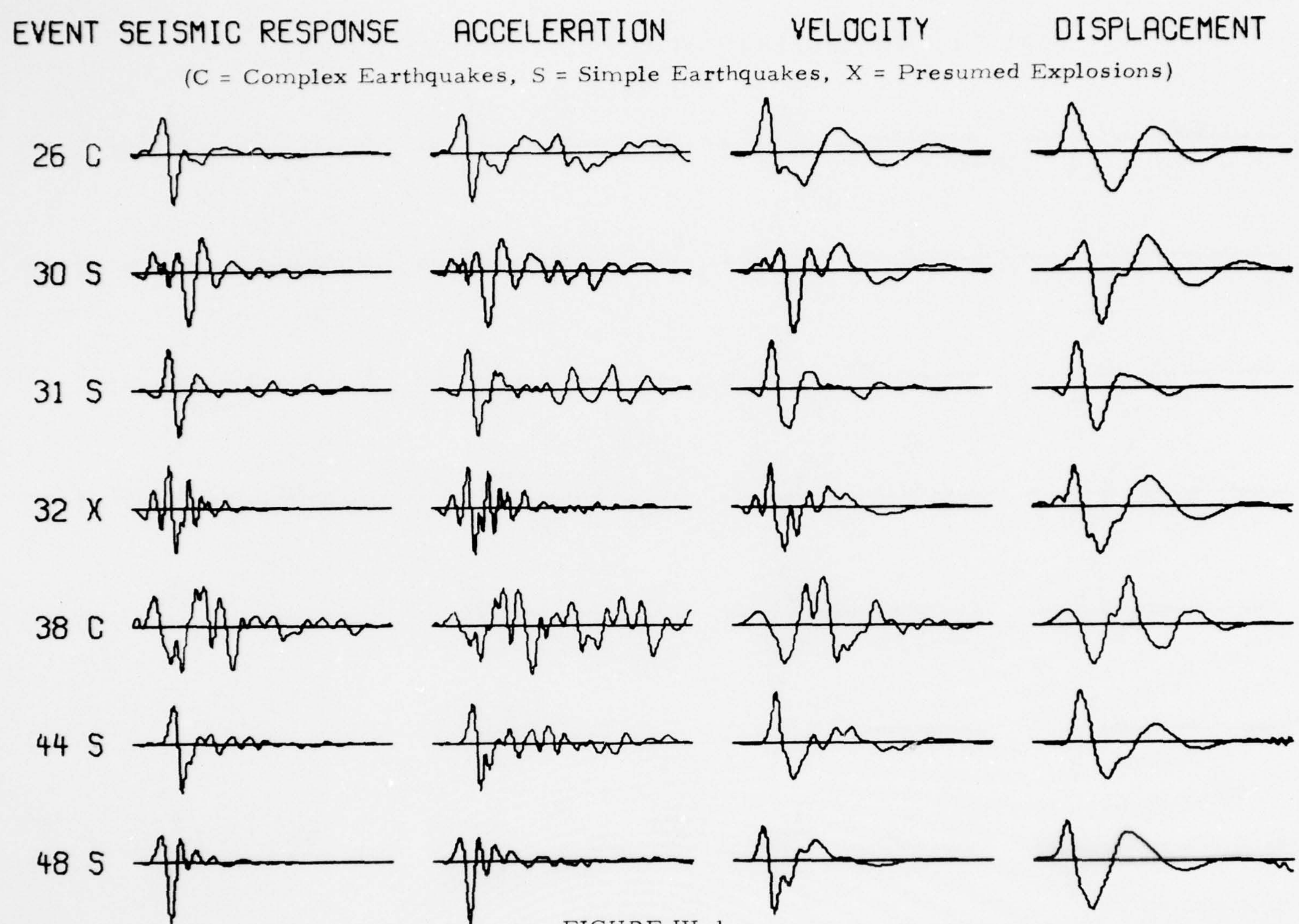


FIGURE III-1

PLOTS OF WAVEFORMS OBTAINED BY CEPSTRUM BEAMFORMING
(PAGE 3 OF 5)

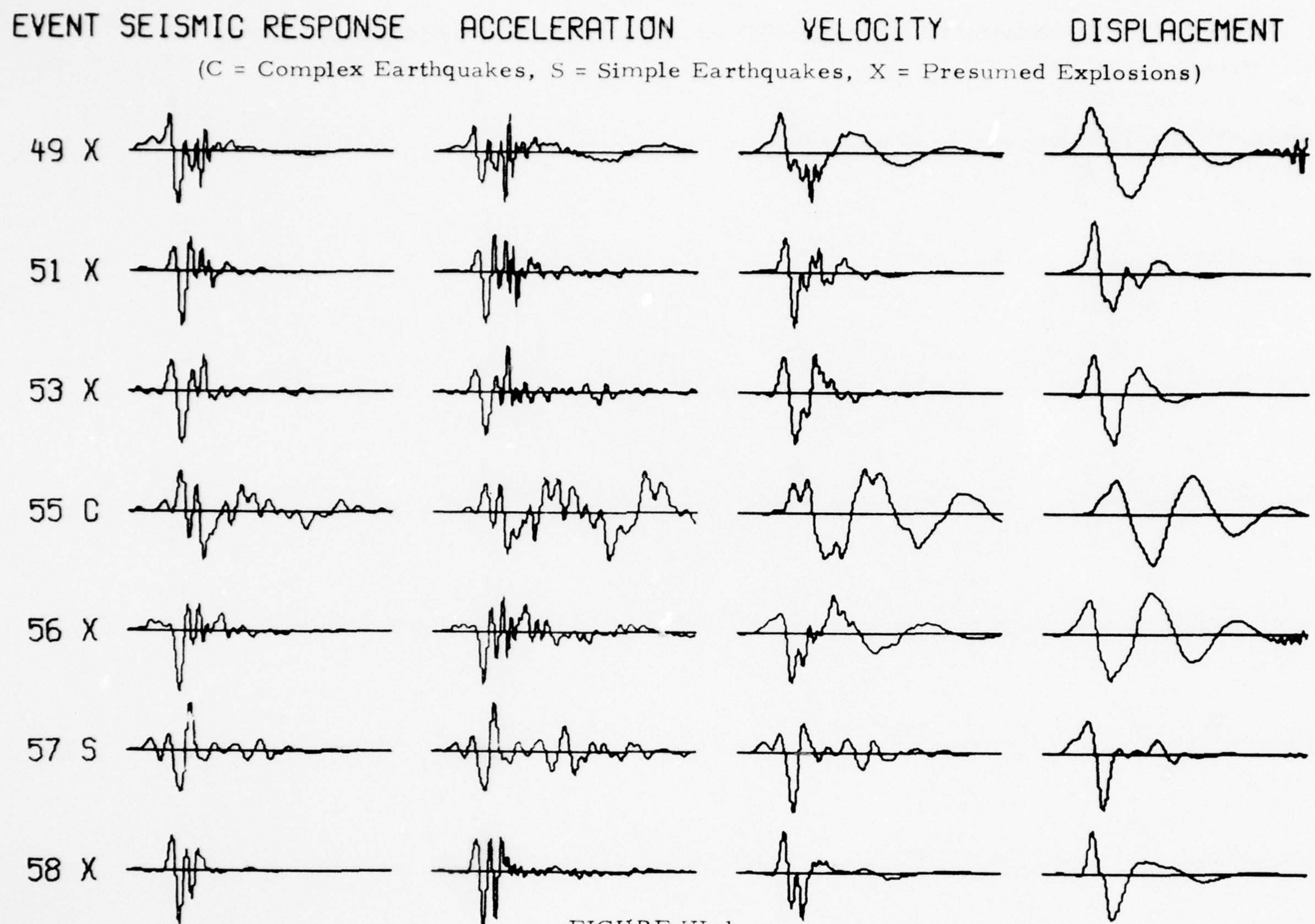


FIGURE III-1

PLOTS OF WAVEFORMS OBTAINED BY CEPSTRUM BEAMFORMING
(PAGE 4 OF 5)

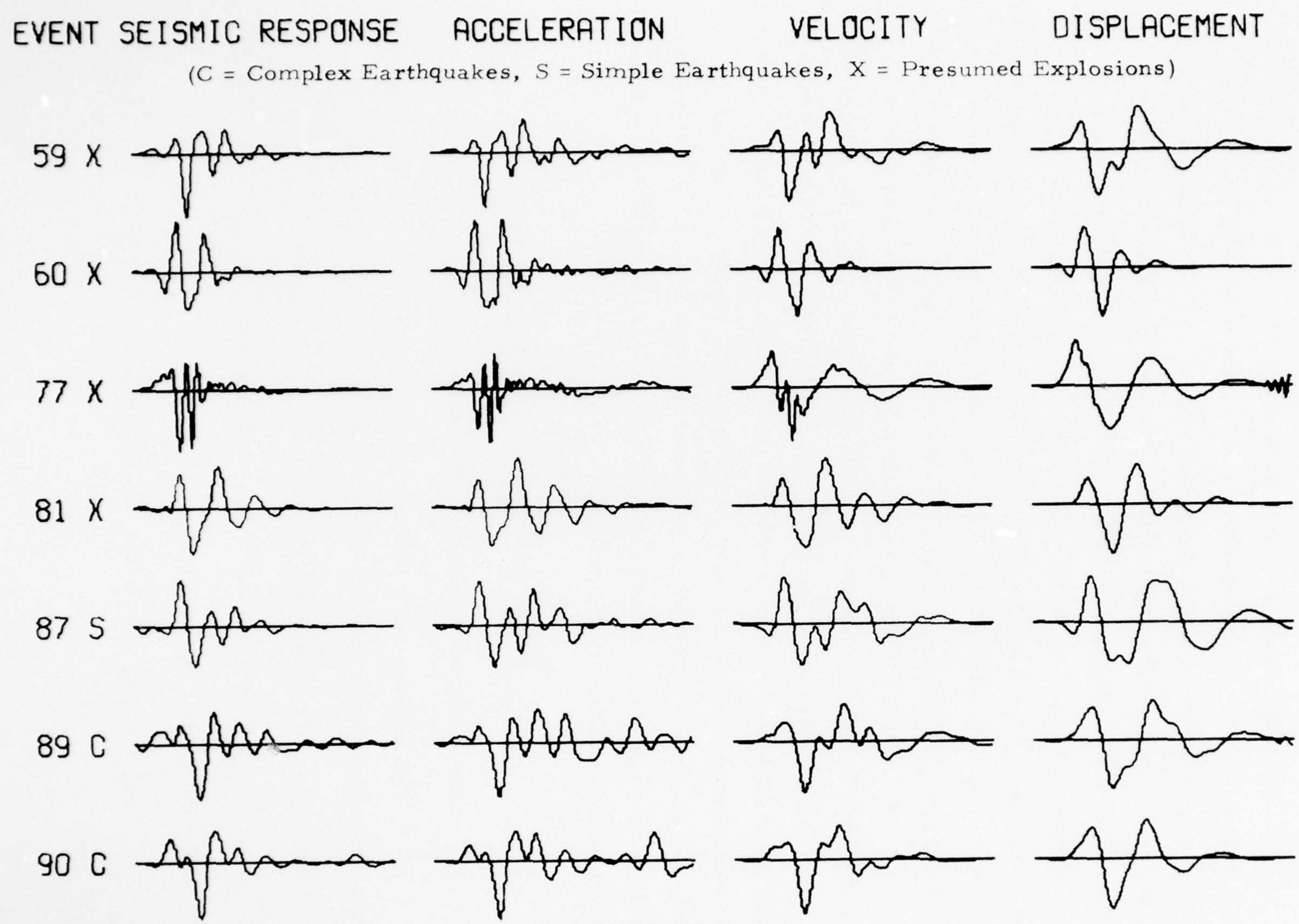


FIGURE III-1

PLOTS OF WAVEFORMS OBTAINED BY CEPSTRUM BEAMFORMING
(PAGE 5 OF 5)

The displacement data of each event were contained in a 6.4 second time window. The data were tapered by exp(-0.01 t) to increasingly weight the data at the start of the signal and to reduce discontinuities at the end of the data sample. The log spectrum of the data was smoothed with a Bartlett window (0.11, 0.22, 0.33, 0.22, 0.11). After transforming back to the time domain, the applied taper was inverted by applying the inverse exponential taper exp (+0.01 t) to the data. The low frequency magnitudes were measured at 0.3, 0.4, and 0.5 Hz. The high frequency magnitudes were measured at 2.5, 3.0, and 4.0 Hz. The center band magnitudes were averaged from 0.75 Hz to 1.75 Hz. The acceleration wavelet of each event was contained in a 3.2 second time window. The data were tapered by exp(-0.02 t). The same Bartlett window was applied. The same frequencies were measured with additional high frequencies measured at 5.0, 6.0, and 8.0 Hz. No subjective measurements of echo delays, deconvolution, or absorption corrections have been applied to the data for this baseline procedure. In future developments, such procedures could be applied, but only if significant gains over the baseline results can be expected.

C. RESULTS OF BASELINE DISCRIMINATION PROCESSING

1. Magnitude from Spectrum Measurement

The average log amplitude measurements between 1.0 and 1.75 Hz are related to network magnitude estimates, m_{bs}, as follows:

For displacement log amplitudes:

$$m_{bs} = \log D + 1.353 \log \sin\Delta + 1.993 \tag{III-1}$$

For acceleration log amplitudes:

$$m_{bs} = \log A + 1.353 \log \sin\Delta + 2.77 \tag{III-2}$$

where

D = logarithm of the displacement spectral amplitude averaged between 1.00 and 1.75 Hz

Δ = epicentral distance in degrees

A = logarithm of the acceleration spectral amplitude averaged between 1.00 and 1.75 Hz.

The constants 1.353, 1.993, and 2.77 were obtained from the data by least squares regression of the data. The results are shown on Figure III-2. For all events, the standard deviation between computed and world-wide network magnitudes was 0.27 for magnitudes computed from average log displacement amplitude and 0.21 for magnitudes computed from average log acceleration amplitude. In the latter case, three anomalously low magnitudes (about one magnitude unit) were computed using acceleration data. This occurred with three earthquakes: events 38, 55, and 89. The result was probably due to nodes in the radiation pattern causing an observed hole in the spectrum at less than 1.75 Hz. The computation of magnitude from displacement amplitude data for these events was also low but by less than 0.5 magnitude units due to heavier weighting of amplitudes at the 1.0 Hz end of the range, which are frequencies lower than the observed hole in the spectrum.

The lower standard deviation of magnitude measurements from log acceleration amplitude measurements is probably due to the fact that the maximum peak-to-peak amplitude through the system response corresponds more closely to ground acceleration than to ground displacement. Based on source theory, the sealing of magnitude as the square root of energy requires that both the log-displacement amplitude and corner frequency be used to estimate magnitude from spectrum. It is possible that the standard deviation of magnitudes computed from ground displacement can be further reduced by such scaling.

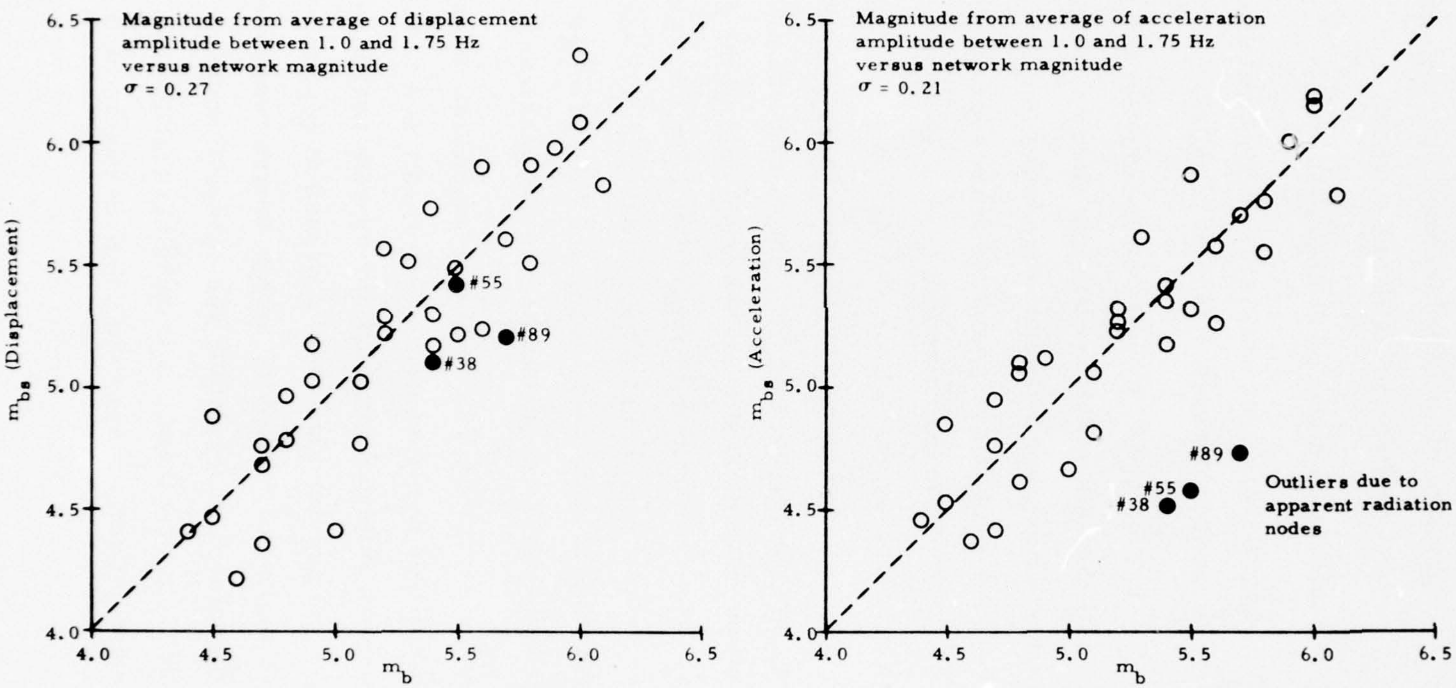


FIGURE III-2

MAGNITUDES COMPUTED FROM SPECTRA

2. Low Frequency and High Frequency Magnitude Measurements

[illegible] the preceding section, it was shown that network magnitude of the events could be reasonably well estimated by averaging log spectrum measurements between 1.0 Hz and 1.75 Hz. In order to statistically compare low frequency and high frequency magnitude measurements of events of different magnitude, the average magnitude between 1.0 and 1.75 Hz was subtracted from the low frequency magnitude and high frequency magnitude measurements. These variable frequency magnitude differences are shown in Table III-3.

The following are definitions of column headings used in Table III-3 and other tables:

- Log D_M - average log displacement amplitude between 1.0 and 1.75 Hz.
- M(0.3) - log displacement amplitude at 0.3 Hz minus Log D_M.
- M(0.4) - log displacement amplitude at 0.4 Hz minus Log D_M.
- M(0.5) - log displacement amplitude at 0.5 Hz minus Log D_M.
- M(2.5) - log displacement amplitude at 2.5 Hz minus Log D_M.
- M(3.0) - log displacement amplitude at 3.0 Hz minus Log D_M.
- M(4.0) - log displacement amplitude at 4.0 Hz minus Log D_M.
- γ(0.3) - log log spectrum rolloff between 0.3 and 0.4 Hz.
- γ(0.4) - log log spectrum rolloff between 0.4 and 0.5 Hz.
- γ(2.5) - log log spectrum rolloff between 2.5 and 3.0 Hz.
- γ(3.0) - log log spectrum rolloff between 3.0 and 4.0 Hz.
- Log A_M - average log acceleration given for reference only.

TABLE III-3

VARIABLE FREQUENCY MAGNITUDE
(PAGE 1 OF 2)

Event Number	Log D_M	M (0.3)	M (0.4)	M (0.5)	M (2.5)	M (3.0)	M (4.0)	γ (0.3)	γ (0.4)	γ (2.5)	γ (3.0)	Log A_M
01	3.09	0.86	0.88	0.84	-0.58	-1.11	-1.82	0.16	-0.41	-6.69	-5.68	2.34
02	3.79	0.66	0.83	0.83	-0.97	-1.90	-2.11	1.36	0.00	-11.74	-1.68	2.67
04	3.96	-0.14	0.14	0.34	-0.87	-1.17	-2.38	2.24	2.06	-3.79	-9.68	2.36
06	2.58	1.15	1.30	1.24	-0.80	-1.00	-1.48	1.20	-0.62	-2.52	-3.84	1.96
07	3.58	0.50	0.66	0.76	-0.26	-0.47	-1.22	1.28	1.03	-2.65	-6.00	2.87
11	3.56	0.84	1.24	1.42	-0.92	-0.99	-1.13	3.20	1.86	-0.88	-1.12	2.81
13	3.84	0.17	0.19	0.16	-0.42	-0.73	-1.61	0.16	-0.31	-3.91	-7.04	2.81
14	3.85	0.66	0.88	0.90	-1.71	-1.81	-1.89	1.76	0.21	-1.26	-0.64	2.76
15	3.24	1.06	1.28	1.33	-1.41	-1.47	-1.54	1.76	0.52	-0.76	-0.56	2.57
16	3.11	0.93	1.02	0.85	-0.51	-0.89	-1.13	0.72	-1.75	-4.80	-1.92	2.47
17	2.86	1.51	1.45	1.26	-0.98	-1.64	-1.78	0.48	-1.96	-8.33	-1.12	1.92
20	2.62	1.53	1.53	1.38	-0.73	-1.10	-1.75	0.00	-1.55	-4.67	-5.20	2.06
21	3.90	0.74	0.89	0.95	-1.80	-2.51	-2.58	1.20	0.62	-8.97	-0.56	3.07
22	4.40	0.56	0.72	0.78	-1.31	-1.50	-2.09	1.28	0.62	-2.40	-4.72	3.45
26	2.98	1.01	1.04	0.91	-1.36	-1.87	-2.40	0.24	-1.34	-6.44	-4.24	2.27
30	3.39	0.72	0.88	0.84	-1.41	-1.65	-1.95	1.28	-0.41	-3.03	-2.40	2.59
31	3.25	0.37	0.62	0.77	-1.13	-1.41	-2.47	2.00	1.55	-3.54	-8.48	2.57
32	3.54	0.70	0.79	0.70	-0.55	-0.62	-1.68	0.72	-0.93	-0.88	-8.48	2.82
38	3.64	0.36	0.65	0.70	-0.94	-1.24	-2.68	2.32	0.51	-3.28	-11.52	2.01
44	2.77	0.86	0.97	0.96	-0.60	-1.00	-1.97	0.88	-0.10	-5.05	-7.76	2.08

M = spectral magnitude levels

γ = log log spectral slope

TABLE III-3

VARIABLE FREQUENCY MAGNITUDE
(PAGE 2 OF 2)

Event Number	Log D_M	M (0.3)	M (0.4)	M (0.5)	M (2.5)	M (3.0)	M (4.0)	γ (0.3)	γ (0.4)	γ (2.5)	γ (3.0)	Log A_M
48	3.08	0.65	0.82	0.78	-1.25	-1.60	-1.77	1.36	-0.41	-4.42	-1.36	2.40
49	3.07	1.14	1.14	0.99	-0.35	-1.16	-1.01	0.00	-1.54	-10.22	1.20	2.34
51	3.59	0.33	0.43	0.45	-0.57	-0.78	-1.22	0.80	0.21	-2.65	-3.52	2.84
53	4.38	0.20	0.55	0.73	-0.64	-0.78	-1.56	2.80	1.85	-1.76	-6.24	3.67
55	3.36	1.18	1.22	1.06	-0.72	1.04	-1.01	0.32	-1.65	-4.04	0.24	2.08
56	2.71	0.82	1.03	1.01	-0.25	0.76	-1.28	1.68	-0.21	-6.44	-4.16	1.98
57	3.34	0.19	0.32	0.37	-1.99	-1.87	-2.60	1.04	0.51	-11.11	-5.84	2.49
58	3.90	0.53	0.74	0.81	-0.18	0.60	-1.28	1.68	0.72	-5.30	-5.44	3.22
59	3.21	0.72	0.91	0.86	-0.92	-1.45	-1.68	1.52	-0.52	-6.69	-1.84	2.45
60	3.81	0.36	0.54	0.67	-0.76	-1.13	-2.51	1.44	1.34	-4.67	-11.04	3.14
77	2.66	1.19	1.27	1.19	0.10	-0.27	-1.39	0.64	-0.83	-4.67	-8.96	1.99
81	3.27	0.90	1.20	1.37	-1.47	-1.79	-1.43	2.40	1.75	-4.04	2.88	2.53
87	3.99	1.07	1.25	1.23	-1.44	-1.56	1.65	1.44	-0.21	-1.51	-0.12	3.26
89	3.23	0.97	1.12	1.08	-1.70	-2.14	-2.20	1.20	0.41	-5.56	-0.44	1.99
90	3.94	0.83	1.06	1.13	-1.15	-1.77	-1.92	1.84	0.72	-7.83	-1.20	3.01
MEAN (Q)	--	0.79	0.93	0.92	-1.12	-1.54	-2.02	1.20	-0.10	-4.50	-3.12	--
SD (Q)	--	0.41	0.35	0.27	0.37	0.41	0.41	0.61	1.02	1.82	2.31	--
MEAN (X)	--	0.65	0.78	0.77	-0.36	-0.70	-1.34	1.04	-0.10	-4.29	-5.12	--
MEAN (N)	--	0.93	1.24	1.37	-1.27	-1.42	-1.37	2.45	1.37	-1.89	0.40	--

Q = earthquakes; X = central Asia presumed explosions; N = western U.S.A. presumed explosions

M = spectral magnitude levels γ = log log spectral slope

Positive values of the γ's indicate increasing amplitude with frequency; negative, decreasing. Multiplication of the γ's by 6.0 would indicate measured dB/octaves on a log amplitude versus log frequency plot of the spectrum. Thus the statistics in Table III-3 characterize the high and low frequency spectrum by levels and slopes of the log log spectral plot of the event. The procedure used to generate Table III-3 was standardized. Several of the events were run several times; the results were reproducible. At the end of Table III-3, the MEAN (Q) represents the average earthquake spectrum statistics; MEAN (X), average of central Asia presumed explosions (excluding event 60 as an outlier); and MEAN (N), average western United States presumed explosions (excluding event 59 as an outlier). SD(Q) is the estimate of the standard deviation of the representative earthquake population. In the western United States presumed explosion population, event 59 was cast out from the mean as an outlier, as was event 60, from the central Asian population.

A special case for application of the event spectral discrimination measurements is to plot the low frequency magnitude, m_L, versus the high frequency magnitude, m_H, where

$$m_L = m_B + M(0.3)$$

and

$$m_H = m_B + M(4.0). \qquad \text{(III-3)}$$

The results are shown on Figure III-3.

3. Multivariate Spectral Discrimination

The variable frequency magnitude data (see Table III-3) are transformed into detectability data. The measurement vector:

$$\underline{X} \; ; \; [M(0.3), M(0.4), M(0.5), M(2.5), M(3.0), M(4.0), \gamma(0.3), \gamma(0.4), \gamma(2.5), \gamma(3.0)] \qquad \text{(III-4)}$$

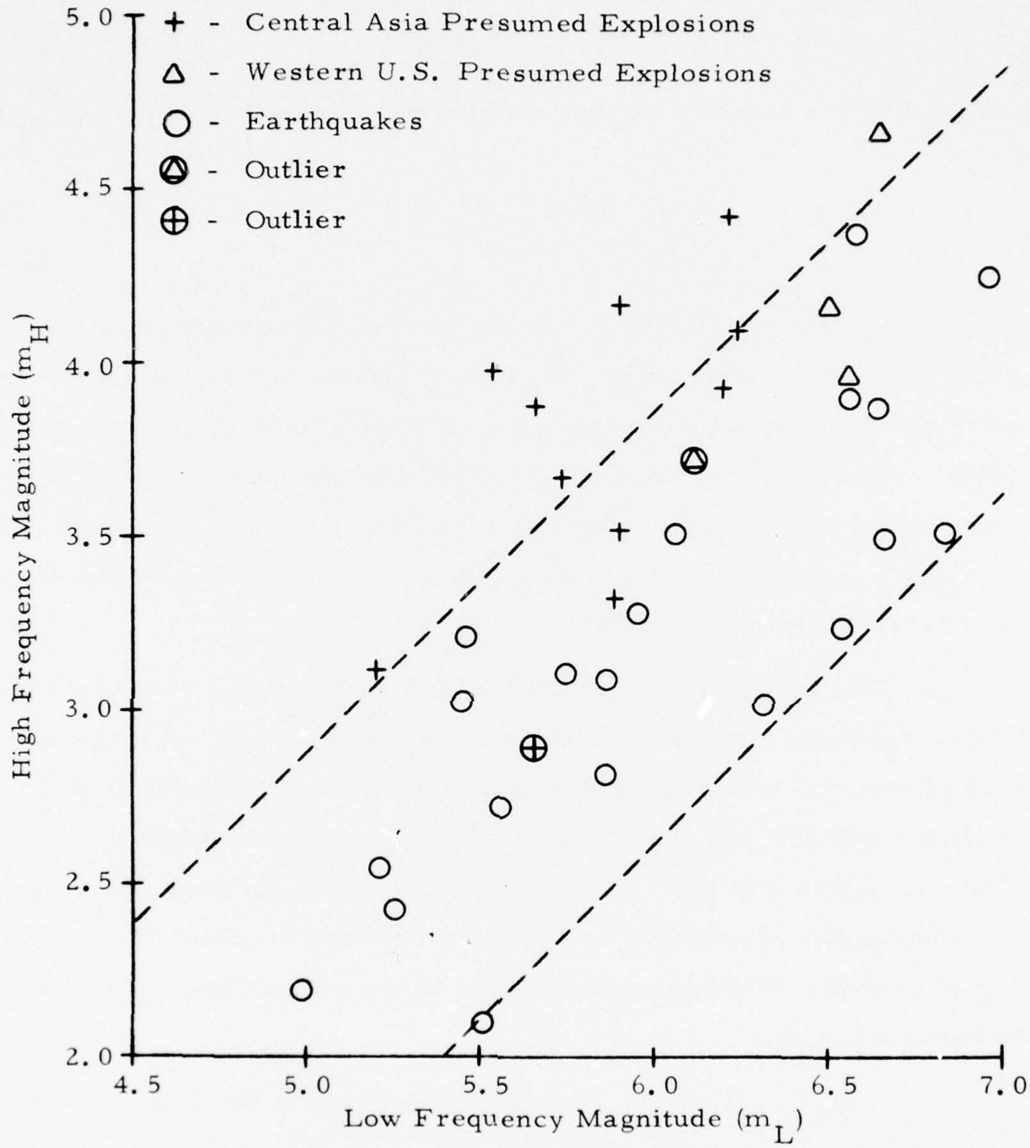


FIGURE III-3

VARIABLE FREQUENCY MAGNITUDE DISCRIMINATION PLOT

has subtracted from it the mean of the earthquake population $E_Q(\underline{X})$, where:

$$E_Q(\underline{X}) \ ; \ [0.79,\ 0.93,\ 0.92,\ -1.12,\ -1.54,\ -2.02,\ 1.20,\ -0.10,\ -4.50,\ -3.12]\ , \qquad \text{(III-5)}$$

and is divided by the standard deviation of the earthquake population, $SD_Q(\underline{X})$, where:

$$SD_Q(\underline{X}) \ ; \ [0.41,\ 0.35,\ 0.27,\ 0.37,\ 0.41,\ 0.41,\ 0.61,\ 1.02,\ 1.82,\ 2.31]\ . \qquad \text{(III-6)}$$

For earthquakes, the detectability is a unit normal Z-statistic. The mean $\gamma(2.5)$ and $\gamma(3.0)$ were taken at the 50 percent levels, and the standard deviations were computed by weighting positive deviations only which are most relevant for discrimination. Obtaining $\underline{X}$ from Table III-3 and using the above values for $E_Q(\underline{X})$ and $SD_Q(\underline{X})$, detectabilities were computed for all 35 events as $\left(X - E_Q(\underline{X})\right)/SD_Q(\underline{X})$ with the results shown on Table III-4, for the earthquake and presumed explosion data.

The information contained in Table III-4 is the basic data for designing an optimum least squares multivariate discrimination process using measures of spectral levels and spectral rolloffs. Each component of the earthquake detectability, $\underline{D}_Q$, in Table III-4 is theoretically a unit variance, zero mean, Gaussian statistic. Each component of one or more presumed explosion populations is possibly detectable as a large variation from the mean. For example, the mean detectability of the central Asian presumed explosion population is:

$$E(\underline{D}_X) \ ; \ [-0.34,\ -0.42,\ -0.57,\ 2.05,\ 2.04,\ 1.66,\ -0.25,\ -0.08,\ 0.10,\ -0.84]\ . \qquad \text{(III-7)}$$

The dominant statistics are significantly elevated high frequency spectral levels. Low frequency levels tend to be consistently lower than earthquakes, and the rolloff between 3.0 and 4.0 Hz is steeper than earthquakes. The mean detectability for western United States presumed explosions is:

TABLE III-4

DETECTABILITY DATA
(PAGE 1 OF 2)

Event Number	M (0.3)	M (0.4)	M (0.5)	M (2.5)	M (3.0)	M (4.0)	γ (0.3)	γ (0.4)	γ (2.5)	γ (3.0)
01	0.17	-0.14	-0.30	1.46	1.05	0.51	-1.70	-0.30	-1.20	-1.11
02	-0.32	-0.29	-0.33	0.41	-0.88	-0.22	0.25	0.10	-3.98	0.62
04	-2.27	-2.26	-2.15	0.68	0.90	-3.07	1.70	2.12	0.39	-2.83
06	0.88	1.06	1.19	0.86	1.32	1.32	0.00	-0.51	1.09	-0.31
07	-0.71	-0.77	-0.59	2.32	2.61	1.95	0.13	1.11	1.02	-1.25
11	0.12	0.89	1.85	0.54	1.34	2.17	3.28	1.92	1.99	0.87
13	-1.51	-2.11	-2.81	1.89	1.98	1.00	-1.70	-0.21	0.32	-1.70
14	-0.32	-0.14	-0.07	-1.59	-0.66	0.32	0.92	0.30	1.78	1.07
15	0.66	1.00	1.52	-0.78	0.17	1.17	0.92	0.61	2.05	1.11
16	0.33	0.26	-0.26	1.65	1.59	2.17	-0.79	-1.62	-0.16	0.52
17	1.76	1.49	1.26	0.38	-0.24	0.59	-2.75	-1.82	-2.10	0.87
20	1.80	1.71	1.70	1.05	1.07	0.66	-1.97	-1.42	-0.09	-0.90
21	-0.12	-0.11	0.11	-1.84	-2.37	-1.37	0.00	0.71	-2.46	1.11
22	-0.56	-0.60	-0.52	-0.51	0.10	-0.17	0.13	0.71	1.15	-0.69
26	0.54	0.31	-0.04	-0.65	-0.80	-0.93	-1.57	-1.22	-1.07	-0.48
30	-0.17	-0.14	-0.30	-0.78	-0.27	0.17	0.13	0.30	0.81	0.31
31	-1.02	-0.89	-0.56	-0.03	0.32	-1.10	1.31	1.62	0.53	-2.32
32	-0.22	-0.40	-0.81	1.54	2.24	0.83	-0.79	-0.81	1.99	-2.32
38	-1.05	-0.80	-0.81	0.49	0.73	-1.61	1.84	0.60	0.67	-3.64
44	0.17	0.11	0.15	1.40	1.32	0.12	-0.52	0.00	-0.30	-2.01

M = spectral magnitude levels γ = log log spectral slope

TABLE III-4

DETECTABILITY DATA

(PAGE 2 OF 2)

Event Number	M (0.3)	M (0.4)	M (0.5)	M (2.5)	M (3.0)	M (4.0)	γ (0.3)	γ (0.4)	γ (2.5)	γ (3.0)
48	-0.34	-0.31	-0.52	-0.35	-0.15	0.61	0.26	-0.30	0.04	0.76
49	0.85	0.60	0.26	2.08	0.93	2.46	-1.97	-1.41	-3.14	1.87
51	-1.12	-1.43	-1.74	1.49	1.85	1.95	-0.66	0.30	1.01	-0.17
53	-1.44	-1.09	-0.70	1.30	1.85	1.12	2.62	1.91	1.51	-1.35
55	0.95	0.83	0.52	1.08	1.22	2.46	-1.44	-1.52	0.25	1.45
56	0.07	0.29	0.33	2.35	1.90	1.80	0.79	-0.11	-1.07	-0.45
57	-1.46	-1.74	-2.03	0.35	-0.80	-1.41	-0.26	0.60	-3.63	-1.17
58	-0.63	-0.54	-0.40	2.54	2.29	1.80	0.79	0.80	-0.44	-1.00
59	-0.17	-0.06	-0.03	0.54	0.22	0.83	0.52	-0.41	-1.20	0.55
60	-1.05	-1.11	-0.93	0.97	1.00	-1.20	0.39	1.41	-0.09	-3.42
77	0.98	0.97	1.00	3.30	3.10	1.54	-0.92	-0.72	-0.09	-2.53
81	0.27	0.77	1.67	-0.95	-0.61	1.44	1.97	1.81	0.25	2.60
87	0.68	0.91	1.15	-0.86	-0.05	0.90	0.39	-0.11	1.64	1.30
89	0.44	0.54	0.59	-1.57	-1.46	0.44	0.00	-0.30	-0.58	1.16
90	0.10	0.37	0.78	-0.08	-0.56	0.24	1.05	0.80	-1.83	0.83

M = spectral magnitude levels γ = log log spectral slope

$E(\underline{D}_N)$; [0.34, 0.89, 1.68, -0.40, 0.30, 1.59, 2.06, 1.45, 1.43, 1.53]. (III-8)

The dominant statistics are progressively increasing spectral levels at low frequencies, significantly elevated spectra at 4.0 Hz, significantly more steeply increasing spectral slopes at low frequencies, and less rolloff at high frequencies. The coherence between $E(\underline{D}_X)$ and $E(\underline{D}_N)$ is 0.05 indicating that the events represented by the average detectability $E(\underline{D}_X)$ are detectable to an almost completely independent basis from those events detectable by $E(\underline{D}_N)$. Thus at least two distinct sets of weights must be derived to optimally detect presumed explosions from western United States and from central Asia.

The performance of an optimum multivariate detector depends not only on the mean of the signal classes being detected, but also on their variation from the mean signal model. The difference from mean signal models $E(\underline{D}_X)$ and $E(\underline{D}_N)$ are shown on Table III-5. The covariance matrices for earthquake errors and presumed explosion errors are shown on Table III-6. The large variances for $\gamma(2.5)$ and $\gamma(3.0)$ (the last two diagonal values of earthquake area variances on Table III-6) are due to using positive deviations to compute the last two elements of $SD_Q(\underline{X})$.

The least squares equation for optimizing the detection of presumed explosions from central Asia is as follows. Elements of the symmetric earthquake correlation matrix, [R], are R_{ij}:

$$R_{ij} = \frac{1}{K-1} \sum_{k=1}^{K} X_i(k)\, X_j(k) \qquad \text{(III-9)}$$

where

K = the number of earthquakes used, and

X_i = the ith element of $\underline{X}$, which is the vector of measured discriminants.

TABLE III-5

PRESUMED EXPLOSIONS ERROR DATA

	Event Number	M (0.3)	M (0.4)	M (0.5)	M (2.5)	M (3.0)	M (4.0)	γ (0.3)	γ (0.4)	γ (2.5)	γ (3.0)
Central Asia	07	-0.37	-0.34	-0.03	0.27	0.56	0.29	0.39	1.11	0.90	-0.38
	13	-1.17	-1.68	-2.25	-0.16	-0.07	-0.66	-1.44	-0.21	0.20	-0.83
	16	0.67	0.69	0.30	-0.40	-0.46	0.51	-0.53	-1.62	-0.28	1.39
	32	0.12	0.03	-0.25	-0.51	0.19	-0.83	-0.53	-0.81	1.87	-1.45
	49	1.19	1.03	0.82	0.03	-1.12	0.80	-1.71	-1.41	-3.26	2.74
	51	-0.78	-1.00	-1.18	-0.56	-0.20	0.29	-0.40	0.30	0.89	0.70
	53	-1.10	-0.66	-0.14	-0.75	-0.20	-0.54	2.88	1.91	1.39	-0.48
	56	0.41	0.72	0.89	0.30	-0.15	0.14	1.05	-0.11	-1.19	0.42
	58	-0.29	-0.11	0.16	0.49	0.24	0.14	1.05	0.80	-0.56	-0.13
	77	1.32	1.40	1.56	1.28	1.05	-0.12	-0.66	-0.72	-0.21	-1.66
Western U.S.A.	11	-0.22	0.00	0.18	0.94	1.05	0.58	1.23	0.48	0.56	-0.65
	15	0.32	0.11	-0.15	-0.37	-0.12	-0.42	-1.13	-0.83	0.62	-0.41
	81	-0.07	-0.12	0.00	-0.55	-0.90	-0.15	-0.08	0.37	-1.18	1.08

M = spectral magnitude levels γ = log log spectral slope

TABLE III-6

COVARIANCE MATRICES
(PAGE 1 OF 2)

Earthquakes Error Data

1.00	0.97	0.94	0.09	0.10	0.93	-0.94	-0.89	0.03	0.81
	0.97	0.96	0.03	0.09	0.92	-0.77	-0.81	0.17	0.82
		1.00	-0.02	0.07	0.87	-0.60	-0.68	0.25	0.80
			0.99	0.83	0.23	-0.37	-0.17	-0.18	-0.74
				1.02	0.37	-0.13	-0.12	0.79	-0.77
					1.50	-0.75	-0.87	0.50	1.14
						1.55	1.06	0.66	-0.56
							1.02	0.11	-0.71
								2.94	-0.19
									2.36

TABLE III-6

COVARIANCE MATRICES
(PAGE 2 OF 2)

Presumed Explosions Error Data

Central Asia Events

0.80	0.83	0.80	0.30	-0.01	0.23	0.50	-0.73	-0.80	0.35
	0.93	0.99	0.33	0.01	0.24	-0.18	-0.59	-0.77	0.30
		1.17	0.39	0.09	0.24	0.22	-0.30	-0.71	0.21
			0.37	0.21	0.07	-0.13	-0.09	-0.35	-0.20
				0.34	-0.13	0.14	0.20	0.44	-0.67
					0.28	-0.16	-0.18	-0.54	0.58
						1.87	1.22	0.75	-0.43
							1.27	0.81	-0.54
								2.17	-1.41
									1.78

Western U. S. Events

0.08	0.02	-0.04	-0.14	-0.10	-0.13	-0.31	-0.20	0.08	-0.03
	0.01	0.01	0.01	0.05	-0.01	-0.06	-0.07	0.10	-0.09
		0.03	0.11	0.10	0.08	0.20	0.11	0.00	-0.03
			0.66	0.76	0.39	0.81	0.28	0.47	-0.53
				0.96	0.41	0.75	0.14	0.79	-0.80
					0.27	0.60	0.29	0.12	-0.18
						1.40	0.75	0.04	-0.21
							0.53	-0.34	0.21
								1.05	-0.95
									1.08

The summation K is over the earthquake population. The optimization is furthered by casting out large negative deviations of the dot product $\left(E\,(\underline{D}_X)\cdot\underline{X}\right)$ $<- \text{SQRT}\left(E\,(\underline{D}_X)\cdot E\,(\underline{D}_X)\right)$. Thus the least squares process makes no attempt to reduce the variance contributions of large negative earthquake deviations as these are easy to discriminate. If a much larger data base were used to design the optimum multivariate discriminant, then $\left(E\,(\underline{D}_X)\cdot\underline{X}\right) < 0$ would be cast out as only positive earthquake errors result in false positive earthquake identification. As a result of this condition, the large negative detectabilities, which obviously indicate earthquakes, are unconstrained.

A covariance matrix $[R']$ is constructed for a combined population of earthquakes and presumed explosions from central Asia, $\underline{D}_X$. Let $\overline{\underline{U}\,(m)}$ be the vector of average detectabilities of presumed explosions from the mth region or explosions medium type. For example, from the central Asian set, m = 1, and $\overline{U_i(1)}$ is the ith element of $\overline{\underline{U}(1)}$, elsewhere referred to as $E\,(\underline{D}_X)$:

$$[S]_m = S_{ij}(m) = \frac{1}{K-1}\sum_{k=1}^{K}\left[U_i(k,m) - \overline{U_i(m)}\right]$$

$$* \left[U_j(k,m) - \overline{U_j(m)}\right]. \qquad \text{(III-10)}$$

$[S]_m$ is the covariance matrix of signal errors from the mth region or explosion medium type. $[S]_m$ is shown on the bottom of Table III-6 for m = 1, central Asian presumed explosion types, and for m = 2, western United States presumed explosion types. The covariance $[R']$ which combines the variance due to earthquake errors and presumed explosion errors is:

$$R'_{ij}(m) = a\cdot\left[\overline{U_i(m)}\;\overline{U_j(m)} + S_{ij}(m)\right] + (1-a)\,R_{ij}\,. \qquad \text{(III-11)}$$

The scalar factors, a, where $(0 \leq a \leq 1)$ and $(1-a)$, provide the designer the option to relatively weight the minimization of errors due to presumed explosion deviations and the errors due to earthquakes in the assumed mixed population. For example, if $a=1$, the multivariate discriminant minimizes the variance of the explosion population and ignores the variance due to earthquakes. If $a=0$, presumed explosion errors are neglected and positive deviations of earthquakes are minimized. Several trials have indicated that the multivariate discriminants are more effective if a is close to zero.

The least squares solution for the optimum multivariate discriminant $\underline{W}(m)$ for presumed explosion events from the mth region is:

$$\underline{W}(m) = [R']^{-1} \overline{\underline{U}(m)} \qquad \text{(III-12)}$$

where the elements of the vector $\overline{\underline{U}(m)}$, the expected value of detectabilities of the mth signal region or medium type, is $\overline{U_i(m)}$.

In obtaining stable solutions for $\underline{W}(1)$ for the central Asian events and $\underline{W}(2)$ for the western United States events, the off-diagonal elements of the matrix $[R']$ must be multiplied by a positive factor, b, equal to or less than one. The solution is considered stable if the maximum absolute change in the solution (given an iteration of the off-diagonal weighting factor b) is less than $\tau \cdot (1-b) \cdot \mathrm{SQRT}\left(\underline{W}(n) \cdot W(n)\right)$. In our case, b was taken as 0.99 and τ as 3.0. The solution vectors $\underline{W}(n)$ were normalized so that the expected value of a presumed explosion was 1.0 and of an earthquake was 0.0. For the central Asian presumed explosions, the off-diagonal elements of $[R']$ were multiplied by 0.94 and for the western United States, 0.93. This satisfied the above conditions for a stable solution. The solution for the central Asian presumed explosions is:

$$\underline{W}(1) = [-0.07, -0.07, -0.07, 0.20, 0.10, 0.20, 0.05, 0.04, 0.00, 0.04] \qquad \text{(III-13)}$$

and for the western United States presumed explosions,

$$\underline{W}(2) = [0.02, 0.03, 0.13, 0.05, 0.02, 0.08, 0.05, 0.26, 0.03, 0.08] . \qquad \text{(III-14)}$$

The coherence between $\underline{W}(1)$ and $\underline{W}(2)$ is 0.31. Thus, $\underline{W}(1)$ and $\underline{W}(2)$ provide a nearly independent basis for detecting events from the two regions. Figure III-4 shows the results obtained by plotting $\underline{W}(1) \cdot \underline{X}$, the component directed toward the central Asian set of presumed explosions versus $\underline{W}(2) \cdot \underline{X}$, the component directed toward the western United States presumed explosion component.

The set of vectors $\underline{W}(n)$, which are used to weight discriminants of events from N regions or medium types, are in general correlated. To obtain an independent and orthogonal basis for detecting events of N types, the set $\underline{W}(n)$ is replaced by a set of unit normalized orthogonal vectors, $\underline{W}'(n)$. Let:

$$\underline{Y}(n) = \underline{W}(n) / |\underline{W}(n)| . \qquad n = 1, 2, \ldots N. \qquad \text{(III-15)}$$

The correlation matrix of the set of vectors $\underline{Y}(n)$ is an N x N matrix [A], where:

$$A_{kn} = \underline{Y}(k) \cdot \underline{Y}(n) . \qquad \text{(III-16)}$$

From the above normalization, the diagonal elements of [A] (i=j) are 1.0; the off-diagonal element magnitudes, the coherence between the vectors $\underline{Y}(k)$ and $\underline{Y}(n)$; and the sign of the off-diagonal elements, the sense of the correlation between Y(k) and Y(n). The solution for the matrix of independent orthogonal unit vectors $\underline{W}'(n)$ are as follows:

$$[\ \underline{W}'(n)\ ] = [A]^{-1} [\ \underline{W}(n)\ ] , \qquad \text{(III-17)}$$

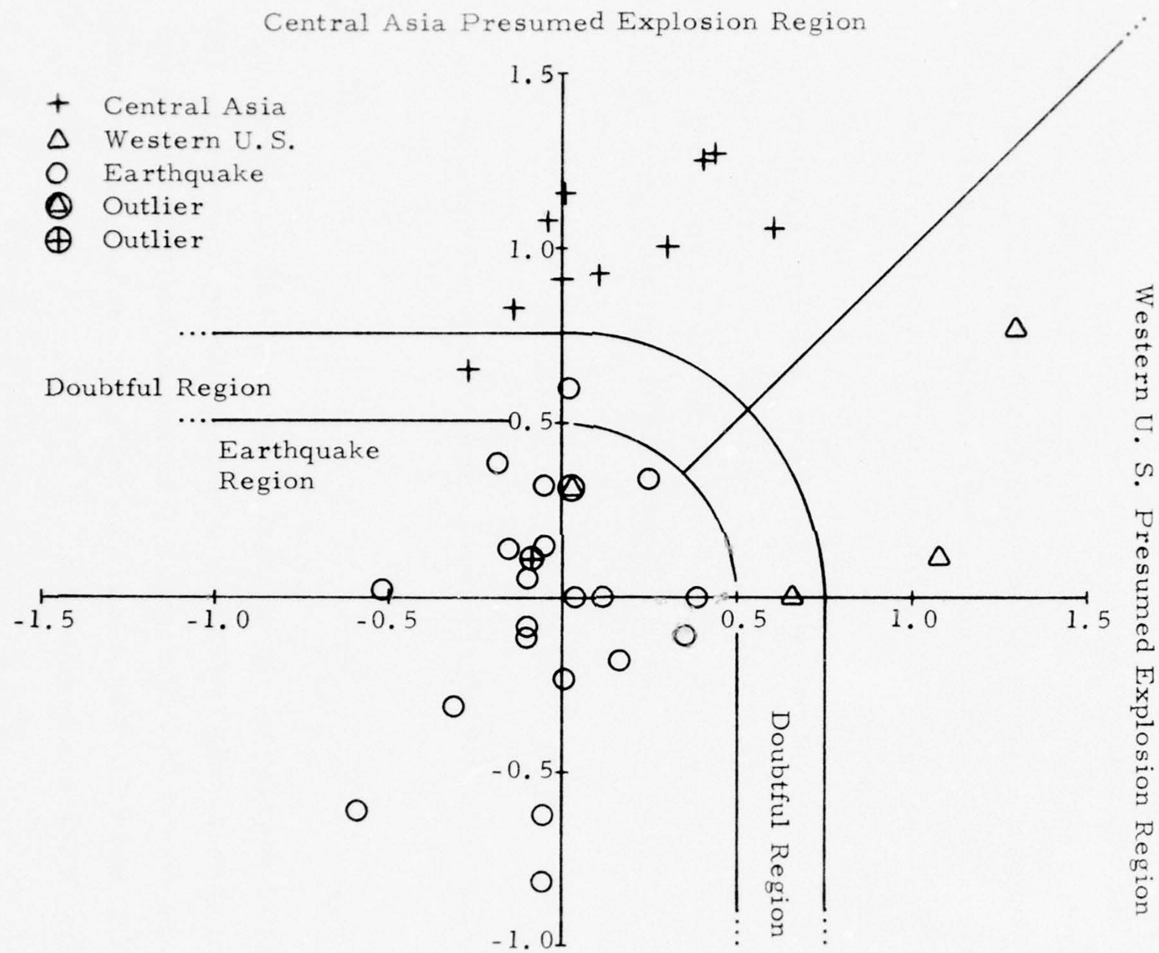


FIGURE III-4

MULTIVARIATE DISCRIMINANTS NOT ORTHOGONALIZED

where $[\underline{W}'(n)]$ and $[\underline{W}(n)]$ are M x K for M regions or medium types, and each row of the matrices is a set of weights to be multiplied over the K-measured event discriminant $\underline{X}$. The detection measure $\underline{D}$ of M components is obtained as:

$$\underline{D} = [\ W'(n)\ ]\ \underline{X}\,. \qquad \text{(III-18)}$$

The resultant set of discriminants $\underline{D}$ can be interpreted as projections on unit vectors, each designating a signal type. For example, m= 1 for central Asian events and m= 2 for the western United States events:

$$A^{-1} = \begin{bmatrix} 1.1027 & - & -0.3364 \\ -0.3364 & & 1.1027 \end{bmatrix}. \qquad \text{(III-19)}$$

The resultant discriminants are plotted on Figure III-5. These are the orthogonal vector component projections of the event detectability vectors. These can be compared to $\underline{W}(n) \cdot \underline{X}$ plotted on Figure III-4. For these, the vectors $\underline{W}(n)$ are not orthogonal, but are least squares solutions normalized to an expected value of 1.0 for presumed explosions and 0.0 for earthquakes. In both cases, no weight was given to reduction of large negative deviations. The data for Figure III-4 are given under columns (5) and (6) of Table III-7. The data for Figure III-5 are given under columns (7) and (8) of Table III-7. The data under columns (1) and (2) are the discriminants using the average detectability of presumed explosions from region 1 (central Asia) and from region 2 (western United States). Under columns (3) and (4) are the orthogonalized projections. These perform less effectively than the least squares discriminants because of the highly correlated state of the spectrum levels and slopes shown on Table III-6.

Also on Table III-7 are shown hyper-space projections of the discriminants. Negative detectabilities are weighted by zero and others are weighted by one. The orthogonalized projections into M source regions are

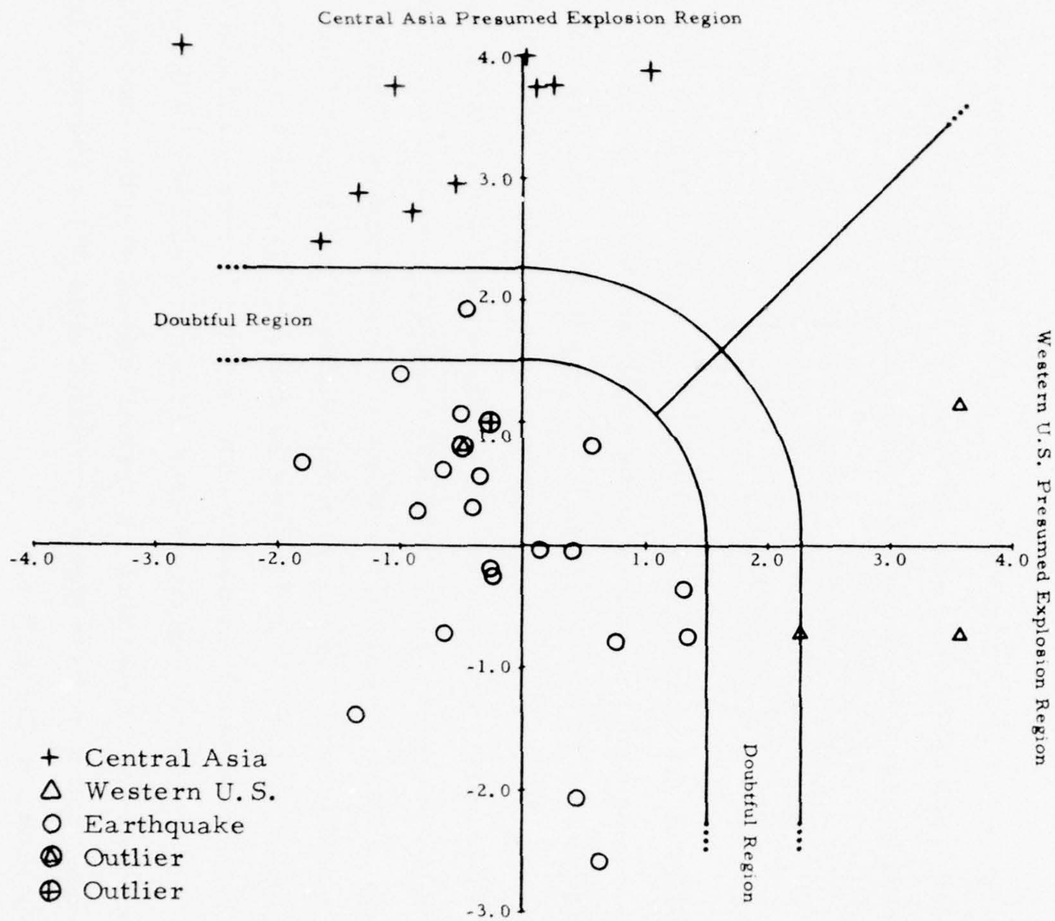


FIGURE III-5

MULTIVARIATE DISCRIMINANTS ORTHOGONALIZED

TABLE III-7

SUMMARY OF MULTIVARIATE SHORT-PERIOD SPECTRAL EVENT DISCRIMINANTS
(PAGE 1 OF 2)

	Event Number	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
Earthquakes	01	0.59	-0.43	0.16	-0.09	0.38	-0.19	1.46	-1.04	1.46	1.00	0.00	0.16	1.00	0.00
	02	0.15	-0.33	-0.04	-0.08	0.05	-0.10	0.29	-0.43	0.29	1.00	0.00	0.00	0.00	0.00
	04	0.23	-0.49	0.06	-0.12	0.14	-0.15	0.62	-0.66	0.62	1.00	0.00	0.06	1.00	0.00
	06	0.45	0.33	0.13	0.08	0.33	0.26	0.81	0.56	0.98	0.68	0.32	0.15	0.73	0.27
	14	-0.38	0.41	-0.10	0.09	-0.19	0.17	-0.80	0.78	0.78	0.00	1.00	0.09	0.00	1.00
	17	-0.06	-0.30	-0.02	-0.07	-0.32	-0.31	-0.72	-0.73	0.00	0.00	0.00	0.00	0.00	0.00
	20	0.36	-0.09	0.10	-0.01	-0.09	-0.10	-0.20	-0.26	0.10	1.00	0.00	0.00	0.00	0.00
	21	-0.97	-0.17	-0.28	-0.05	-0.81	-0.05	-2.62	0.64	0.64	0.00	1.00	0.00	0.00	0.00
	22	0.02	0.01	0.01	0.00	-0.00	0.04	-0.05	0.13	0.13	0.00	1.00	0.04	1.00	0.00
	26	-0.32	-0.48	-0.10	-0.12	-0.60	-0.57	-1.39	1.36	0.00	0.00	0.00	0.00	0.00	0.00
	30	-0.14	0.07	-0.03	0.01	-0.10	-0.10	-0.24	-0.24	0.00	0.00	0.00	0.01	0.00	1.00
	31	0.11	-0.09	0.03	-0.02	0.02	0.12	-0.08	0.40	0.40	0.00	1.00	0.03	1.00	0.00
	38	0.29	-0.29	0.08	-0.06	0.01	-0.24	0.28	-0.85	0.28	1.00	0.00	0.08	1.00	0.00
	44	0.59	-0.24	0.16	-0.05	0.31	-0.06	1.08	-0.50	1.08	1.00	0.00	0.31	1.00	0.00
	48	-0.01	0.06	-0.00	0.02	0.15	-0.06	0.54	-0.35	0.54	1.00	0.00	0.02	0.00	1.00
	55	0.57	0.19	0.16	0.05	0.60	0.04	1.94	-0.47	1.94	1.00	0.00	0.17	0.91	0.09
	57	-0.02	-0.86	-0.02	-0.21	0.03	-0.51	0.63	-1.80	0.63	1.00	0.00	0.00	0.00	0.00
	87	-0.21	0.56	-0.05	0.13	-0.12	0.36	-0.77	1.35	1.35	0.00	1.00	0.13	0.00	1.00
	89	-0.69	0.09	-0.20	0.01	-0.63	-0.05	-2.03	0.46	0.46	0.00	1.00	0.01	0.00	1.00
	90	-0.22	0.23	-0.06	0.05	0.01	0.38	-0.39	1.32	1.32	0.00	1.00	0.05	0.00	1.00

TABLE III-7

SUMMARY OF MULTIVARIATE SHORT-PERIOD SPECTRAL EVENT DISCRIMINANTS
(PAGE 2 OF 2)

	Event Number	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
Region 1	07	1.22	0.14	0.35	0.05	1.28	0.44	3.74	0.23	3.75	1.00	0.00	0.35	1.00	0.00
	13	1.16	-0.68	0.32	0.15	1.07	-0.50	4.04	-2.80	4.04	1.00	0.00	0.35	0.82	0.18
	16	0.80	-0.01	0.23	0.01	0.82	-0.15	2.88	-1.35	2.88	1.00	0.00	0.23	1.00	0.00
	32	0.98	-0.23	0.27	-0.04	0.64	-0.30	2.43	-1.66	2.43	1.00	0.00	0.27	1.00	0.00
	49	0.66	-0.18	0.19	-0.03	0.81	-0.03	2.70	-0.92	2.70	1.00	0.00	0.19	1.00	0.00
	51	0.99	-0.07	0.28	-0.00	1.15	0.03	3.75	-1.02	3.75	1.00	0.00	0.28	1.00	0.00
	53	0.81	0.43	0.24	0.12	1.06	0.61	2.84	1.04	3.02	0.88	0.12	0.27	0.80	0.20
	56	0.91	0.15	0.26	0.05	1.00	0.30	2.99	0.03	2.99	1.00	0.00	0.26	1.00	0.00
	58	1.13	0.10	0.32	0.04	1.25	0.40	3.71	0.10	3.71	1.00	0.00	0.32	1.00	0.00
	77	1.34	-0.11	0.38	-0.00	0.92	0.10	2.92	-0.57	2.92	1.00	0.00	0.38	1.00	0.00
Region 2	11	0.36	1.24	0.12	0.30	0.76	1.28	1.17	3.66	3.84	0.09	0.91	0.32	0.14	0.86
	15	-0.15	0.77	-0.03	0.18	-0.01	0.65	-0.71	2.24	2.24	0.00	1.00	0.18	0.00	1.00
	81	-0.40	0.99	-0.10	0.23	0.12	1.07	-0.72	3.56	3.56	0.00	1.00	0.23	0.00	1.00
Outliers	59	0.19	0.04	0.05	0.01	0.35	0.02	1.12	-0.29	1.12	1.00	0.00	0.06	0.96	0.04
	60	0.48	-0.43	0.13	-0.10	0.21	-0.08	0.79	-0.50	0.79	1.00	0.00	0.13	1.00	0.00

given as a length and the square of the direction cosines. For M= 2 (central Asia and western United States) the least squares discriminant is shown by a length under column (9), squared direction cosine of the region 1 component (central Asia) under column (10), and squared direction cosine with region 2 under column (11).

The length and squared direction cosine components are shown for the discriminant derived from the mean detectabilities of region 1 and region 2 under columns (12), (13), and (14). For the earthquakes shown in Table III-7 (page 1), the length of the least squares projection was zero for 40 percent of the complex earthquakes and 20 percent of the simple earthquakes. For 40 percent of each type of earthquake the dominant projection was toward region 1. For 40 percent of the simple earthquakes and 20 percent of the complex earthquakes, the projection was toward region 2. The lengths of the earthquake projections were all less than the length of presumed explosions with the exception of the two outliers shown on page 2 of Table III-7.

SECTION IV

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

The need to perform interactive discrimination processing in the surveillance mode stems from the following problems:

- The methodology which optimizes discrimination processing is not yet known. Therefore, programmatic changes in discrimination processing procedures will need to be rapidly implemented on-line. An analyst can be computer-assisted and prompted under the constraint of a programmed set of standard operating procedures for performing the discrimination processing. Any such programmed changes in the analyst's procedures must be shown to significantly improve the analyst's discrimination performance using his old set of standards as a baseline.

- Certain tasks such as picking the start time of an event, detection and removal of echos, absorption correction, and other interpretive tasks may be performed better by an analyst than by any automatic procedure. But the introductions of analyst interpretation, even if constrained by standard operating procedures, trade off reproducibility of results. The projected gains of such processing must be verified and shown to be statistically significant.

- In some difficult tasks such as discrimination processing, interactive processing by an analyst is a necessary transition to more optimal and reproducible automatic processing. The exact definition of the task and the criteria for optimizing the task must be learned.

- As optimum automatic processing procedures evolve, the analyst will function primarily in response to emergency conditions. Some of these are: to detect and cope with overloading due to event swarms, etc.; to perform extended and more subjective analyses on events of doubtful origin.

The development and demonstration of the Short-Period Earthquake/Explosion Discrimination Package (SPEED) partially fulfills the above needs for interactive discrimination processing. Our demonstrated capabilities have indicated that a substantial fraction of the required interactive processing capability has been developed. Also, the considerable amount of support data processing for editing events, selecting channels, and for time alignment of stations has been developed.

Some of the principal problems remaining to be solved are as follows:

- Automation of support data processing:
  - select out bad channels
  - time align channels
  - pick event start time
  - detect and correct station or component polarity reversals.
- Extend and provide needed improvements to the SPEED options:
  - correct time series for absorption with option of reprocessing data corrected for absorption
  - provide analyst capability to pick start times with automatic correction for initial offset
  - improve cepstrum analysis to more unambiguously determine echo delays; if possible, automatically determine echo delays and derive source parameter information from the cepstrum of the signal waveform

- provide an option to correct the event waveform for multiple scattered echos instead of just for single integer delay echos
- change the Variable Frequency Magnitude (VFM) program to measure magnitudes and rolloffs at an analyst-selected set of frequencies instead of for just a single high and low frequency magnitude measurement
- expand the list of short-period discriminant variate measurements and possibly also include long-period discriminant variate measurements which improve overall discrimination performance.

- Extend seismic command language capability:
  - compile event tables of discrimination variates derived from SPEED processing
  - compile event population plots of discrimination variates derived from SPEED processing
  - compile output tapes of standard format discriminant information for extended least squares multivariate discriminant analysis.

These recommended improvements may not all be achievable due to storage limitations of the PDP-15 computer. In some cases they may have to be performed as support processing on the IBM 360/44 rather than as SPEED options when such storage limitations are encountered.

In order to establish a performance baseline on utilizing SPEED as a routine event discrimination processor, a data base of representative earthquakes and explosions was processed. This baseline processing was specified as simply as possible and could be performed reproducibly in an automatic mode. The baseline performance data was obtained by fixed prescribed tapering, smoothing, and inverse tapering of the ground displacement

measurements. Several runs on some of the events indicated that the resultant measurements were reproducible. The measurements were magnitude changes at specified high and low frequencies from the average magnitude between 1.0 and 1.75 Hz. It turned out that the VFM method provides only marginal discrimination capability. It is estimated that about half the presumed explosions are detectable with a false alarm rate of about 2-1/2 percent. As would be expected, better performance could be obtained by utilizing all of the spectral values measured at four low frequencies and four high frequencies. Unexpectedly, it was found that a single set of weights for summing the discriminants could not detect presumed explosions analyzed from central Asia or from the western United States. Two nearly orthogonal sets of weights were required. This means that some finite set of vectors of an unknown dimension are necessarily required for a completely general multivariate spectral discrimination of presumed explosions. Even if such a complete basis for spectral discrimination is derived, there is no guarantee that spectral discrimination is sufficient to eliminate all false negatives associated with certain types of medium or geology.

There is also no guarantee that certain regions may not consistently produce false positive discrimination of earthquakes. The results obtained for multivariate discrimination indicate a standard deviation of 0.94 for the length of positive deviations. This is a conservative estimate obtained by neglecting the zero values of the discriminant; including them, the standard deviation is 0.86. The average presumed explosion discriminant length is 3.21. Assuming normal statistics, this would indicate a 2.5×10^{-4} probability of a false positive discrimination at the 50 percent level of detecting presumed explosions. The standard deviation of negative deviations in the presumed explosions population (possible false negatives) is 0.53. The 90 percent detection threshold for presumed explosions is approximately 2.5 (about 1.3 standard deviations below the mean of the presumed explosion population).

The probability of a false positive discrimination at the 90 percent detection level is estimated at 4.0×10^{-3}. In evaluating the baseline, the two outliers were obtained, both presumed to be peaceful nuclear explosions. From the above statistics, these are most likely not normal statistical variations but indicate incompleteness of the discrimination method in detecting every possible kind of explosion event. Either additional vectors are needed for more complete region or source medium type representation or more components are needed in the multivariate discriminant vector $\underline{X}$. It is probable that more discriminants other than the spectral discriminants analyzed are needed to discriminate all explosions. It is probable that direct detection of focal depth by methods more precise and reliable than those presently used will be needed to eliminate all systematic false negatives.

SECTION V

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APPENDIX A
EVENT DATA

As part of the quality control in editing the NORSAR data used in this report, a matrix of plots of all of the event data was prepared for use by a data analyst. The plots included all sensors and subarray beams and also a window of noise preceding the event. The analyst by visual inspection of this data estimated the start time of the event, eliminated faulty channels, channels with polarity reversals, clipped channels, and those channels or subarrays showing no visual indication of event information on the channel or subarray beam. The remaining channels were then cepstrum beamformed and corrected for system response.

An additional quality control step was applied to the remaining operating good channels by comparing the spectrum of the element to a window of noise preceding the event. If at some frequency the spectrum of the noise exceeded the spectrum of the event, then that channel at that frequency was counted as containing no apparent event information. For each event, a summary table was prepared which at each frequency counted the number of channels with no apparent event information. These are presented in Tables A-1 through A-35 for all of the events processed. The tables are labelled by event number. Corresponding event description information is shown on Table III-1. Plots of the cepstrum beamform outputs are shown on Figure III-1. The column heading of frequency index numbers on Tables A-1 through A-35 indicate the number of the frequency estimate of the first row of that column. The index number column on the left side of the table indicates the frequency number increment starting from the top of each column. To

convert frequency index numbers to frequency in Hz, add the frequency index number on the left side of the table to the frequency index number listed across the top of the table, subtract 2, and multiply by 0.0098.

These tables give a powerful quantitative check on the amount of useful event information contained on all of the channels used in the cepstrum beamforming process. In case of alternative analyst picks of the channels containing weak signals and picks of the start time of weak signals, the tables containing lowest numbers and the broadest band of low numbers indicates the preferred analyst interpretation. A quick method of interpreting the tables is to take the largest of the first ten frequency numbers as the expected number of noise channels. A positive indication of seismic information is taken as a channel count of noise at a given frequency number equal to or less than one-tenth of the largest count between frequency number one and ten. The number of event indications by this criteria was observed in the following frequency number bands: 1-525, 526-750, and 751-1025. In the 1-525 band (frequencies less than approximately 5.0 Hz), all of the events indicate significant event information using this criteria. In the 526-750 (frequencies approximately 5.25 Hz to 7.5 Hz), only one out of 20 very large earthquakes (in particular, event number 22) indicated significant energy in this band possibly due to saturation and clipping. Ten out of eleven apparent explosions from eastern Kazakh indicated significant energy in this band. The one exception, event number 32, a possible peaceful explosion (PNE), was displaced several degrees from the other eastern Kazakh epicenters. In the 751-1025 band (frequencies greater than approximately 7.5 Hz), three out of 20 earthquakes were significant in this band; these included event number 22 again but also event numbers 4 and 87, both simple earthquakes. Six out of 11 of the eastern Kazakh events were significant in this band including event number 32, which was missed in the 5.25 Hz to 7.5 Hz band.

NUMBER OF SENSORS WITH SIGNAL LESS THAN NOISE AT GIVEN FREQUENCY INDEX

	1	51	101	151	201	251	301	351	401	451	501	551	601	651	701	75
1	42	31	1	29	0	4	9	11	23	20	37	38	35	35	38	[illegible]
2	42	32	1	27	1	4	10	12	21	19	38	36	36	32	37	[illegible]
3	43	34	1	25	1	3	10	12	21	18	38	36	36	34	37	[illegible]
4	42	33	1	23	2	2	10	12	21	20	37	33	38	36	36	[illegible]
5	43	34	1	19	4	3	12	10	20	21	37	34	39	36	34	[illegible]
6	43	34	1	16	4	4	11	6	18	22	36	35	40	39	33	[illegible]
7	41	33	1	14	4	4	11	5	19	23	35	34	42	38	32	[illegible]
8	41	30	1	12	4	4	11	5	20	22	34	34	42	36	35	[illegible]
9	41	29	1	12	4	3	12	6	22	25	34	35	41	37	36	[illegible]
10	41	28	1	12	4	3	12	6	21	27	34	34	43	36	34	[illegible]
11	42	29	3	9	3	4	12	6	25	27	33	35	40	35	36	[illegible]
12	41	29	3	7	3	5	10	5	25	28	31	35	40	34	35	[illegible]
13	40	29	4	7	4	6	10	7	20	27	29	34	40	35	35	[illegible]
14	42	30	5	8	4	4	11	8	22	27	29	35	39	34	37	[illegible]
15	43	28	5	7	4	6	12	11	20	26	27	34	39	33	38	[illegible]
16	44	30	6	8	3	6	11	11	18	25	25	35	37	35	38	[illegible]
17	44	29	8	7	2	6	10	11	18	24	25	37	35	40	40	[illegible]
18	43	27	8	6	2	5	12	12	18	25	25	41	37	38	38	[illegible]
19	43	25	10	6	2	4	14	12	16	24	29	40	39	39	37	[illegible]
20	44	25	13	5	2	3	16	10	18	23	31	38	42	39	35	[illegible]
21	43	26	12	5	2	3	18	10	20	22	34	36	41	39	34	[illegible]
22	44	26	13	7	2	4	18	11	22	22	35	35	42	42	34	[illegible]
23	44	27	15	8	2	5	18	11	22	21	38	34	43	41	34	[illegible]
24	46	27	15	9	3	5	19	11	22	22	40	32	44	40	32	[illegible]
25	46	25	17	9	3	7	21	11	20	22	40	34	45	40	30	[illegible]
26	44	27	19	9	3	8	21	14	20	23	41	34	45	38	30	[illegible]
27	44	25	21	10	4	9	21	13	23	26	41	34	44	40	29	[illegible]
28	43	28	25	10	4	9	23	12	23	29	39	34	44	38	28	[illegible]
29	45	24	26	12	4	10	25	14	23	28	41	34	45	37	31	[illegible]
30	44	26	27	12	6	11	25	14	22	27	42	36	44	37	32	[illegible]
31	43	23	30	13	6	11	26	14	24	27	39	37	43	37	31	[illegible]
32	40	22	31	11	6	11	27	15	26	25	39	40	42	39	31	[illegible]
33	43	18	34	10	6	12	26	18	23	24	40	40	40	38	30	[illegible]
34	40	14	33	8	6	12	23	18	22	25	38	40	39	38	29	[illegible]
35	39	13	31	7	6	13	18	16	22	27	38	41	41	37	29	[illegible]
36	39	9	29	7	6	13	17	15	20	29	38	41	39	39	29	[illegible]
37	39	6	28	8	6	14	17	16	21	30	36	39	41	39	28	[illegible]
38	41	4	28	8	7	14	14	15	19	31	37	39	39	39	28	[illegible]
39	42	4	27	9	7	15	13	17	20	31	36	42	39	37	30	[illegible]
40	43	4	23	8	6	15	12	19	18	32	36	40	38	37	33	[illegible]
41	42	3	22	8	6	15	13	20	18	31	38	39	37	36	32	[illegible]
42	42	2	25	7	6	16	15	19	17	31	39	36	33	37	32	[illegible]
43	39	1	24	6	6	16	13	18	17	31	39	34	41	37	33	[illegible]
44	38	1	24	4	7	16	12	18	18	33	38	32	39	36	32	[illegible]
45	38	1	25	3	6	13	13	19	18	33	39	33	41	37	34	[illegible]
46	36	1	24	3	6	11	11	22	16	34	39	35	39	37	35	[illegible]
47	36	1	26	3	5	10	11	22	16	36	39	33	39	37	39	[illegible]
48	35	0	27	1	4	9	10	21	19	35	37	35	37	39	39	[illegible]
49	34	0	26	1	4	9	11	18	21	35	36	36	36	38	39	[illegible]
50	34	0	28	1	4	9	12	19	21	35	37	35	39	38	40	[illegible]

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GIVEN FREQUENCY INDEX

401	451	501	551	601	651	701	751	801	851	901	951	1001
23	20	37	38	35	35	38	38	35	30	38	31	28
21	19	38	36	36	32	37	38	34	29	36	30	31
21	18	38	36	36	34	37	36	34	28	34	30	29
21	20	37	33	38	36	36	34	34	30	34	28	32
20	21	37	34	39	36	34	35	35	32	30	31	32
18	22	36	35	40	39	33	34	34	32	30	31	33
19	23	35	34	42	38	32	32	34	33	31	32	33
20	22	34	34	42	36	35	33	36	32	32	33	33
22	25	34	35	41	37	36	30	39	28	32	35	34
21	27	34	34	43	36	34	33	39	30	32	33	34
25	27	33	35	40	35	36	34	37	30	33	35	32
25	28	31	35	40	34	35	36	39	29	33	35	31
20	27	29	34	40	35	35	35	37	29	35	37	31
22	27	29	35	39	34	37	32	35	30	37	38	31
20	26	27	34	39	33	38	32	35	32	35	38	28
18	25	25	35	37	35	38	34	35	29	35	39	29
18	24	25	37	35	40	40	33	37	28	34	35	30
18	25	25	41	37	38	38	33	36	29	34	36	27
16	24	29	40	39	39	37	32	33	28	33	38	28
18	23	31	38	42	39	35	32	31	28	32	37	30
20	22	34	36	41	39	34	33	27	30	31	35	28
22	22	35	35	42	42	34	33	27	29	29	32	29
22	21	38	34	43	41	34	36	30	27	30	30	29
22	22	40	32	44	40	32	37	28	28	30	32	29
20	22	40	34	45	40	30	37	30	28	31	31	29
20	23	41	34	45	38	30	38	30	27	33	26	
23	26	41	34	44	40	29	37	32	26	33	27	
23	29	39	34	44	38	28	35	33	28	34	28	
23	28	41	34	45	37	31	35	32	29	30	27	
22	27	42	36	44	37	32	32	34	32	30	30	
24	27	39	37	43	37	31	35	33	33	31	33	
26	25	39	40	42	39	31	33	34	32	31	31	
23	24	40	40	40	38	30	29	35	33	32	28	
22	25	38	40	39	38	29	31	35	34	31	28	
22	27	38	41	41	37	29	34	32	34	31	29	
20	29	38	41	39	39	29	32	33	35	30	28	
21	30	36	39	41	39	28	31	33	34	30	29	
19	31	37	39	39	39	28	32	33	35	30	28	
20	31	36	42	39	37	30	30	33	38	30	26	
18	32	36	40	38	37	33	28	34	38	29	25	
18	31	38	39	37	36	32	32	33	36	28	25	
17	31	39	36	38	37	32	33	33	37	27	25	
17	31	39	34	41	37	33	31	33	34	30	26	
18	33	38	32	39	36	32	32	33	32	31	29	
18	33	39	33	41	37	34	33	33	30	31	28	
16	34	39	35	39	37	35	35	31	31	34	29	
16	36	39	33	39	37	39	36	31	32	35	29	
19	35	37	35	37	39	39	34	33	35	34	29	
21	35	36	36	36	38	39	34	32	36	33	28	
21	35	37	35	39	38	40	33	33	37	32	28	

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ENT 1

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NUMBER OF SENSORS WITH SIGNAL LESS THAN NOISE AT GIVEN FREQUENCY INDEX

	1	51	101	151	201	251	301	351	401	451	501	551	601	651	701
1	61	4	9	11	0	1	9	0	5	8	13	15	17	27	32
2	62	4	14	14	0	1	9	0	5	8	11	18	17	26	32
3	62	5	17	24	0	1	10	0	5	11	17	18	16	28	31
4	62	6	30	29	0	2	10	0	6	9	19	19	18	28	29
5	58	7	45	25	0	2	11	1	6	5	19	19	18	26	29
6	59	8	51	20	0	2	12	1	5	5	21	21	17	25	25
7	59	8	40	14	0	1	10	2	7	4	22	21	17	24	25
8	58	9	19	8	0	0	11	2	9	3	21	22	17	24	23
9	59	5	10	5	0	0	12	2	7	3	18	22	18	25	23
10	60	4	5	3	0	0	10	1	9	2	16	24	21	22	23
11	59	4	2	1	0	0	9	1	12	2	14	27	22	26	21
12	60	3	1	1	0	0	9	3	12	1	15	26	21	25	21
13	59	2	1	0	0	0	8	3	19	1	12	27	21	24	22
14	61	1	1	0	0	0	10	3	20	2	11	24	20	22	22
15	59	1	0	0	0	0	7	1	19	3	11	24	20	21	24
16	59	1	1	0	0	1	8	1	20	5	11	20	19	23	26
17	61	1	1	0	0	1	8	1	26	4	11	20	21	23	28
18	61	1	1	0	0	1	6	1	28	6	11	20	22	22	24
19	59	2	1	0	0	0	7	1	28	6	15	20	22	24	24
20	59	2	1	0	0	0	5	0	30	7	17	20	22	24	24
21	56	2	2	0	0	0	5	1	26	8	14	19	22	24	23
22	59	1	1	0	0	0	5	1	28	10	13	17	22	23	23
23	58	0	1	0	0	0	4	2	24	10	12	18	20	25	25
24	59	0	1	0	0	1	5	2	25	8	12	17	19	23	24
25	57	0	1	0	0	2	6	2	19	9	11	18	20	23	29
26	55	0	0	0	0	3	5	2	18	8	12	20	19	19	28
27	51	0	0	0	0	3	5	2	17	7	13	20	17	20	28
28	48	1	0	0	0	3	5	2	12	11	15	20	17	20	27
29	48	1	0	0	0	5	4	2	13	12	16	23	16	22	26
30	45	1	0	0	0	6	4	2	11	11	16	24	14	24	25
31	42	1	0	0	0	6	2	2	9	11	15	24	15	25	24
32	40	1	0	0	0	5	1	2	8	10	16	23	15	25	23
33	38	1	0	0	0	8	1	3	9	12	15	22	20	25	25
34	38	1	0	0	0	9	2	4	9	10	15	21	20	26	28
35	37	1	0	0	0	7	2	4	9	10	20	21	21	26	27
36	37	1	0	0	0	9	2	4	8	11	17	21	21	26	28
37	35	1	0	0	0	8	3	4	8	8	17	21	20	26	29
38	30	1	0	0	0	7	3	4	8	7	18	19	20	28	28
39	27	0	0	0	0	9	2	4	7	8	18	17	21	28	29
40	25	1	0	0	0	9	0	5	6	9	18	19	22	27	28
41	23	1	0	0	0	7	1	5	6	7	19	18	23	26	29
42	22	2	0	0	0	5	2	3	6	8	17	16	23	28	31
43	18	2	0	0	1	5	2	3	5	8	15	17	24	28	30
44	17	3	0	0	1	5	2	3	4	8	15	15	27	28	30
45	15	3	1	0	2	5	1	3	3	8	17	16	30	28	31
46	11	5	1	0	2	4	0	3	5	9	19	16	32	31	29
47	10	5	1	0	2	4	0	3	5	9	17	18	32	31	27
48	8	7	1	0	2	5	0	2	6	8	17	18	32	28	23
49	6	7	2	0	2	6	0	2	8	14	16	18	31	29	24
50	6	7	7	0	2	5	0	2	8	14	16	18	26	31	24

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GIVEN FREQUENCY INDEX

401	451	501	551	601	651	701	751	801	851	901	951	1001
5	8	13	15	17	27	32	22	26	21	20	25	25
5	8	11	18	17	26	32	23	25	24	22	23	24
5	11	17	18	16	28	31	20	25	23	21	23	26
6	9	19	19	18	28	29	19	25	23	23	23	28
6	5	19	19	18	26	29	20	26	24	24	24	22
5	5	21	21	17	25	25	23	27	24	25	25	24
7	4	22	21	17	24	25	25	28	23	24	29	25
9	3	21	22	17	24	23	25	28	21	24	27	26
7	3	18	22	18	25	23	23	31	22	22	26	25
9	2	16	24	21	22	23	22	29	23	20	23	27
12	2	14	27	22	26	21	20	32	23	21	24	26
12	1	15	26	21	25	21	20	31	22	23	25	28
19	1	12	27	21	24	22	22	29	22	23	26	25
20	2	11	24	20	22	22	22	30	22	26	28	24
19	3	11	24	20	21	24	22	26	22	26	29	26
20	5	11	20	19	23	26	25	24	21	25	29	25
26	4	11	20	21	23	28	27	20	21	25	28	24
28	6	11	20	22	22	24	31	20	22	25	31	24
28	6	15	20	22	24	24	29	18	23	24	31	22
30	7	17	20	22	24	24	27	17	25	22	32	22
26	8	14	19	22	24	23	27	15	24	23	32	25
28	10	13	17	22	23	23	26	13	23	24	30	29
24	10	12	18	20	25	25	25	17	22	25	28	31
25	8	12	17	19	23	24	27	18	23	23	32	33
19	9	11	18	20	23	29	28	22	21	22	28	32
18	8	12	20	19	19	28	28	25	21	19	28	
17	7	13	20	17	20	28	26	26	20	18	24	
12	11	15	20	17	20	27	29	26	20	17	24	
13	12	16	23	16	22	26	27	26	20	16	25	
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9	11	15	24	15	25	24	26	25	19	18	26	
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9	12	15	22	20	25	25	23	22	20	18	25	
9	10	15	21	20	26	28	21	21	20	18	25	
9	10	20	21	21	26	27	22	20	19	20	24	
8	11	17	21	21	26	28	22	21	20	21	23	
8	8	17	21	20	26	29	23	20	21	24	24	
8	7	18	19	20	28	28	21	18	19	25	22	
7	8	18	17	21	28	29	23	20	20	28	21	
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6	7	19	18	23	26	29	27	20	21	26	19	
6	8	17	16	23	28	31	28	21	20	27	20	
5	8	15	17	24	28	30	27	22	20	24	22	
4	8	15	15	27	28	30	27	21	16	23	21	
3	8	17	16	30	28	31	29	20	19	22	21	
5	9	19	16	32	31	29	28	17	18	26	22	
5	9	17	18	32	31	27	26	17	18	26	25	
6	8	17	18	32	28	23	25	18	19	26	26	
8	14	16	18	31	29	24	24	19	19	25	27	
8	14	16	18	26	31	24	25	17	19	24	26	

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NUMBER OF SENSORS WITH SIGNAL LESS THAN NOISE AT GIVEN FREQUENCY INDEX

	1	51	101	151	201	251	301	351	401	451	501	551	601	651	701
1	54	15	0	0	1	1	5	11	7	2	8	18	24	12	22
2	54	12	0	0	1	1	5	12	5	4	8	18	24	12	21
3	53	9	1	0	2	1	6	13	5	4	7	20	27	11	23
4	55	6	1	0	2	1	4	13	6	5	7	19	28	12	21
5	52	6	3	0	2	1	4	12	5	7	7	17	27	12	19
6	50	5	3	0	2	2	3	13	6	6	7	18	26	14	18
7	53	2	4	1	2	2	3	16	7	5	5	20	24	16	18
8	53	2	4	1	1	1	4	16	6	5	7	21	21	15	17
9	52	1	4	1	1	0	3	14	5	5	7	20	21	17	14
10	50	0	3	0	1	0	3	13	5	6	7	16	20	18	14
11	46	0	3	0	0	0	2	16	5	6	5	13	21	18	15
12	44	0	2	0	0	0	2	17	5	8	4	11	22	16	14
13	44	0	2	0	0	0	2	21	4	8	5	11	20	16	17
14	41	0	2	0	0	0	2	20	5	6	4	14	21	17	16
15	37	0	2	0	0	1	3	19	4	6	6	15	19	18	17
16	35	0	2	0	1	1	2	19	3	6	7	16	20	18	19
17	36	0	2	0	1	0	2	20	2	6	7	20	18	17	19
18	36	0	1	0	0	0	2	20	1	7	7	20	11	18	19
19	37	0	1	1	1	0	2	20	2	7	7	23	15	18	19
20	36	0	1	0	1	0	3	21	4	6	7	23	15	17	20
21	36	0	1	0	1	0	4	21	4	6	7	25	17	15	19
22	35	0	1	0	3	0	5	19	3	6	6	22	17	16	22
23	36	0	0	0	2	0	5	18	5	4	9	25	17	18	22
24	36	0	0	0	2	0	5	18	5	4	8	26	16	21	22
25	35	0	0	0	2	1	5	17	5	5	7	27	15	24	21
26	36	0	0	0	1	1	4	17	5	6	8	29	15	23	22
27	34	0	0	0	0	1	5	14	4	5	9	27	15	25	21
28	36	0	0	1	0	3	4	15	4	4	10	27	16	24	24
29	36	0	0	0	0	2	4	12	2	5	10	29	16	22	26
30	37	0	0	0	0	2	3	12	2	5	11	29	19	20	23
31	35	0	0	0	0	1	3	12	3	6	12	28	19	20	22
32	36	0	0	0	0	2	3	11	3	5	12	28	18	21	18
33	35	0	0	0	0	5	3	11	3	6	10	24	20	21	17
34	33	0	0	0	0	4	3	11	3	9	9	25	19	18	17
35	33	0	0	0	0	4	4	12	3	8	11	25	18	17	20
36	33	0	0	1	0	3	4	10	3	8	13	26	22	17	18
37	33	1	0	1	0	2	4	10	3	9	15	26	22	19	18
38	30	1	0	0	1	2	6	9	6	9	15	26	19	18	19
39	31	1	0	0	2	5	4	9	5	9	14	25	17	22	19
40	30	0	0	0	2	4	4	9	7	9	12	24	15	23	18
41	30	0	0	1	1	4	3	7	8	9	13	25	14	24	18
42	29	0	0	1	1	3	3	6	7	9	15	26	14	23	18
43	29	0	0	1	1	2	3	6	6	8	16	24	14	22	18
44	28	0	0	1	1	2	4	6	5	8	17	24	14	23	17
45	28	0	0	1	1	1	6	8	5	9	11	23	12	21	15
46	27	0	0	0	1	3	4	7	4	11	13	22	13	22	17
47	25	0	0	0	1	2	5	6	5	10	14	22	14	21	16
48	22	0	0	0	0	1	8	6	4	8	14	23	11	23	14
49	20	0	0	1	0	1	6	6	3	7	14	21	13	23	13
50	18	0	0	1	1	3	8	7	2	8	15	22	12	23	12

TABLE A-3
EVENT 4
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IVEN FREQUENCY INDEX

.01	451	501	551	601	651	701	751	801	851	901	951	1001
7	2	8	18	24	12	22	11	11	10	9	4	9
5	4	8	18	24	12	21	10	12	11	8	4	10
5	4	7	20	27	11	23	10	13	10	10	4	12
6	5	7	19	28	12	21	10	15	10	11	4	11
5	7	7	17	27	12	19	11	16	12	10	6	11
6	6	7	18	26	14	18	11	18	12	10	6	10
7	5	5	20	24	16	18	11	19	12	10	6	11
6	5	7	21	21	15	17	10	19	12	10	6	11
5	5	7	20	21	17	14	12	19	13	12	7	9
5	6	7	16	20	18	14	14	20	12	12	6	9
5	6	5	13	21	18	15	14	20	16	13	5	10
5	8	4	11	22	16	14	12	20	17	13	5	11
4	8	5	11	20	16	17	13	20	15	12	5	11
5	6	4	14	21	17	16	12	17	13	11	7	11
4	6	6	15	19	18	17	13	15	13	13	9	12
3	6	7	16	20	18	19	14	12	12	14	11	15
2	6	7	20	18	17	19	15	14	13	13	10	16
1	7	7	20	11	18	19	15	14	13	13	10	16
2	7	7	23	15	18	19	16	13	13	14	11	16
4	6	7	23	15	17	20	15	15	12	14	13	14
4	6	7	25	17	15	19	14	15	13	16	11	16
3	6	6	22	17	16	22	15	12	14	14	9	19
5	4	9	25	17	18	22	11	11	11	13	9	19
5	4	8	26	16	21	22	11	13	12	13	9	20
5	5	7	27	16	24	21	10	11	13	14	9	22
5	6	8	29	15	23	22	10	11	14	13	9	
4	5	9	27	15	25	21	10	11	12	15	8	
4	4	10	27	16	24	24	13	11	13	15	8	
2	5	10	29	16	22	26	13	9	13	16	7	
2	5	11	29	19	20	23	11	10	16	15	8	
3	6	12	28	19	20	22	12	10	14	14	9	
3	5	12	28	18	21	18	12	10	13	13	7	
3	6	10	24	20	21	17	9	8	15	12	7	
3	9	9	25	19	18	17	9	9	12	10	8	
3	8	11	25	18	17	20	9	6	9	9	9	
3	8	13	26	22	17	18	11	6	9	13	9	
3	9	15	26	22	19	18	10	7	11	12	7	
6	9	15	26	19	18	19	10	7	9	13	7	
5	9	14	25	17	22	19	10	6	8	14	6	
7	9	12	24	15	23	18	12	6	8	16	6	
8	9	13	25	14	24	18	13	6	8	17	6	
7	9	15	26	14	23	18	12	8	9	16	7	
6	8	16	24	14	22	18	14	6	8	14	8	
5	8	17	24	14	23	17	14	6	8	12	9	
5	9	11	23	12	21	15	13	7	8	13	10	
4	11	13	22	13	22	17	14	7	7	13	10	
5	10	14	22	14	21	16	16	8	8	10	10	
4	8	14	23	11	23	14	15	9	8	10	11	
3	7	14	21	13	23	13	13	9	7	9	10	
2	8	15	22	12	23	12	12	10	8	7	9	

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VENT 4
E A-5

NUMBER OF SENSORS WITH SIGNAL LESS THAN NOISE AT GIVEN FREQUENCY INDEX

	1	51	101	151	201	251	301	351	401	451	501	551	601	651	701
1	12	19	5	5	14	8	10	10	12	10	15	7	14	6	8
2	11	19	5	5	14	8	10	11	12	10	14	8	14	5	8
3	11	19	4	6	15	8	10	11	11	10	14	7	13	6	8
4	11	19	4	6	14	8	10	11	12	10	13	6	13	6	7
5	12	17	4	6	14	8	10	11	12	11	12	5	11	5	7
6	12	16	4	7	14	9	8	10	12	10	12	6	10	5	8
7	11	15	2	7	14	10	9	11	11	10	12	6	10	6	8
8	12	15	2	7	14	11	7	11	11	9	15	9	10	6	8
9	12	15	2	7	14	11	7	10	11	7	14	9	10	7	8
10	12	14	2	7	14	11	7	10	10	6	15	9	10	8	9
11	13	11	2	9	15	14	6	10	10	6	13	10	10	8	8
12	13	10	1	10	15	14	7	10	10	6	12	10	11	8	8
13	13	9	1	10	15	14	7	10	10	6	11	10	12	8	9
14	14	10	3	9	13	14	7	8	10	5	9	11	12	7	10
15	16	10	3	7	14	14	7	6	9	4	10	11	12	8	12
16	16	10	3	6	14	12	9	7	8	4	10	11	10	8	13
17	16	9	3	7	12	12	9	6	8	4	10	11	9	5	13
18	18	9	2	6	11	12	10	6	9	4	10	12	8	6	13
19	18	9	3	6	13	12	11	7	11	4	8	11	9	8	14
20	18	10	3	4	13	12	12	8	10	4	8	12	8	6	13
21	17	9	3	4	12	10	13	9	10	5	8	11	8	6	13
22	18	8	4	3	10	10	13	10	9	5	9	11	9	7	13
23	18	8	3	3	11	9	12	12	8	6	8	11	9	7	13
24	18	8	3	3	10	9	12	10	8	7	8	11	9	7	11
25	18	8	3	2	8	9	11	11	7	7	7	10	11	10	11
26	18	8	3	1	9	7	11	12	9	8	7	10	12	10	11
27	18	8	3	1	9	7	9	13	10	8	7	10	13	10	11
28	17	10	3	1	9	6	9	13	10	8	10	8	14	10	11
29	16	10	3	3	12	5	10	11	11	8	10	8	14	10	10
30	18	8	2	4	12	5	10	10	11	8	10	9	13	9	10
31	17	8	3	4	12	5	10	10	13	8	11	9	12	9	11
32	18	8	4	4	12	5	10	11	12	11	11	11	13	9	9
33	18	7	4	5	12	5	11	10	12	12	10	12	15	9	9
34	17	6	4	5	13	5	11	10	11	13	10	11	15	9	9
35	17	6	5	5	13	5	10	10	13	13	10	13	14	8	9
36	15	6	6	5	15	7	10	10	12	12	11	12	13	9	10
37	15	6	6	5	15	6	10	11	13	10	12	12	12	10	10
38	16	5	5	5	14	6	11	13	13	10	12	12	12	10	9
39	15	5	3	5	13	6	11	12	13	12	12	11	11	10	9
40	15	4	3	6	13	6	11	13	13	12	12	11	11	10	8
41	15	5	3	7	14	6	13	12	13	11	13	10	11	9	8
42	15	5	4	9	14	8	12	11	13	12	13	10	11	9	10
43	14	5	4	10	13	8	14	12	13	11	10	11	10	8	10
44	16	6	3	10	11	9	12	12	13	12	8	12	10	7	9
45	17	5	3	10	11	9	10	12	13	14	7	13	9	7	8
46	16	7	4	11	11	9	9	12	11	13	6	13	8	7	8
47	16	6	4	14	10	9	9	11	10	13	7	13	7	7	9
48	16	6	5	14	8	10	10	10	10	16	8	14	8	7	9
49	17	5	5	14	8	10	10	10	9	16	8	14	8	7	9
50	17	5	5	14	8	10	10	11	9	16	8	15	6	8	10

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EVENT 6

T GIVEN FREQUENCY INDEX

401	451	501	551	601	651	701	751	801	851	901	951	1001
12	10	15	7	14	6	8	10	12	7	9	12	10
12	10	14	8	14	5	8	10	10	7	10	11	10
11	10	14	7	13	6	8	11	9	6	10	11	10
12	10	13	6	13	6	7	9	9	6	9	10	10
12	11	12	5	11	5	7	9	10	7	8	10	10
12	10	12	6	10	5	8	9	10	7	8	10	12
11	10	12	6	10	6	8	10	10	6	7	9	13
11	9	15	9	10	6	8	9	11	6	9	8	13
11	7	14	9	10	7	8	10	10	7	9	7	13
10	6	15	9	10	8	9	10	11	7	10	8	13
10	6	13	10	10	8	8	10	10	8	11	8	13
10	6	12	10	11	8	8	10	11	8	10	10	12
10	6	11	10	12	8	9	10	10	7	10	10	12
10	5	9	11	12	7	10	10	10	9	9	9	10
9	4	10	11	12	8	12	9	11	8	10	11	9
8	4	10	11	10	8	13	9	11	6	10	12	11
8	4	10	11	9	5	13	10	10	8	9	12	11
9	4	10	12	8	6	13	10	11	8	10	12	11
11	4	8	11	9	8	14	11	11	9	12	12	12
10	4	8	12	8	6	13	11	13	8	13	12	13
10	5	8	11	8	6	13	9	13	7	12	12	12
9	5	9	11	9	7	13	9	13	8	14	14	11
8	6	8	11	9	7	13	9	13	8	16	15	11
8	7	8	11	9	7	11	10	13	9	15	13	11
7	7	7	10	11	10	11	9	12	9	15	13	11
9	8	7	10	12	10	11	9	14	9	14	12	
10	8	7	10	13	10	11	9	15	9	14	13	
10	8	10	8	14	10	11	10	15	10	14	13	
11	8	10	8	14	10	10	9	14	10	14	12	
11	8	10	9	13	9	10	10	14	11	14	13	
13	8	11	9	12	9	11	10	16	10	13	12	
12	11	11	11	13	9	9	11	16	10	13	12	
12	12	10	12	15	9	9	9	16	9	14	13	
11	13	10	11	15	9	9	8	16	9	13	12	
13	13	10	13	14	8	9	8	14	7	11	13	
12	12	11	12	13	9	10	8	13	6	10	13	
13	10	12	12	12	10	10	9	13	6	10	13	
13	10	12	12	12	10	9	9	13	7	11	13	
13	12	12	11	11	10	9	8	9	6	11	12	
13	12	12	11	11	10	8	9	9	6	12	13	
13	11	13	10	11	9	8	10	8	5	13	12	
13	12	13	10	11	9	10	10	8	7	13	13	
13	11	10	11	10	8	10	10	7	9	13	10	
13	12	8	12	10	7	9	9	7	10	12	10	
13	14	7	13	9	7	8	10	8	11	11	10	
11	13	6	13	8	7	8	10	10	10	11	9	
10	13	7	13	7	7	9	10	9	10	11	9	
10	16	8	14	8	7	9	10	8	10	11	9	
9	16	8	14	8	7	9	10	8	10	11	9	
9	16	8	15	6	8	10	12	9	10	11	10	

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EVENT 6
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UMBER OF SENSORS WITH SIGNAL LESS THAN NOISE AT GIVEN FREQUENCY INDEX

	1	51	101	151	201	251	301	351	401	451	501	551	601	651	701
1	63	26	0	8	0	1	2	2	7	3	7	6	3	15	14
2	63	24	0	10	1	0	2	1	7	4	6	6	4	16	14
3	64	22	0	13	1	0	2	1	4	4	6	6	5	20	13
4	65	19	0	13	1	0	2	2	4	5	5	7	5	17	16
5	65	18	0	14	0	0	1	2	5	5	5	7	6	16	17
6	65	19	0	14	0	0	2	3	6	6	7	7	6	17	19
7	62	17	0	16	0	0	1	2	6	3	7	9	6	17	16
8	63	14	0	18	0	0	1	2	4	3	8	9	6	19	14
9	64	9	0	17	0	0	0	4	4	2	8	10	7	19	15
0	63	9	0	15	0	0	1	4	5	4	11	12	7	12	17
1	64	7	0	12	0	0	1	4	6	4	11	13	8	13	16
2	65	7	0	10	0	0	1	4	6	3	10	14	9	15	15
3	65	7	0	9	0	0	0	5	6	2	10	12	11	15	14
4	64	7	2	8	0	0	0	5	6	3	9	11	10	14	15
5	63	5	2	7	0	0	1	4	5	3	10	11	11	9	13
6	61	4	1	6	0	0	1	3	5	3	8	11	11	11	13
7	61	3	1	5	0	1	1	4	6	3	8	9	6	11	13
8	63	3	0	6	0	1	1	4	5	3	9	9	5	12	14
9	63	3	0	9	0	2	1	4	5	3	8	9	6	11	15
0	65	3	0	9	0	2	2	3	5	3	6	10	6	12	17
1	62	3	0	11	0	1	2	4	4	3	4	9	6	12	16
2	61	2	0	9	1	1	3	4	4	2	5	7	7	10	16
3	60	2	0	12	1	1	3	3	3	2	3	5	7	8	15
4	60	2	0	12	0	1	4	3	3	2	3	3	8	8	15
5	60	2	0	12	1	1	3	4	3	2	3	3	8	9	12
6	62	0	0	15	1	1	3	4	3	2	2	4	8	10	12
7	60	0	0	13	1	1	5	3	2	3	2	3	5	10	11
8	57	0	0	14	1	1	5	3	2	3	2	4	5	11	13
9	59	0	1	11	1	1	5	3	4	4	2	5	4	8	14
0	60	0	1	11	0	1	5	3	4	4	3	5	3	11	16
1	61	0	1	11	0	1	5	2	4	4	4	5	5	11	16
2	64	0	1	7	0	1	5	2	4	4	4	5	7	10	15
3	61	0	1	7	0	1	3	3	5	5	4	5	6	10	13
4	63	0	1	6	0	1	3	2	5	5	4	5	8	11	12
5	63	0	1	4	1	1	3	5	4	5	6	6	9	9	12
6	62	0	1	2	1	1	3	5	4	5	7	5	9	9	14
7	62	0	1	1	0	1	3	5	3	5	9	5	5	8	13
8	62	0	1	1	0	1	3	5	4	5	10	4	6	10	13
9	58	0	1	0	0	2	2	6	5	6	9	4	8	8	13
0	56	0	1	1	0	1	2	6	5	6	9	6	8	10	13
1	56	0	1	1	0	2	3	6	6	5	9	5	10	12	14
2	56	0	1	1	0	1	3	4	6	5	7	6	10	11	16
3	50	0	2	1	0	1	2	4	4	5	6	5	11	12	15
4	46	0	4	1	0	0	2	5	3	5	5	5	11	11	14
5	43	0	4	1	1	0	2	5	2	5	5	4	12	13	14
6	41	0	4	1	1	0	1	6	2	5	6	4	13	15	17
7	41	0	5	1	1	1	1	6	2	5	6	6	10	15	19
8	35	0	5	1	0	1	1	6	3	6	6	4	13	12	17
9	33	0	7	1	0	1	1	6	2	6	7	5	14	13	15
0	31	0	7	0	0	1	2	6	2	6	5	4	15	15	17

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GIVEN FREQUENCY INDEX

401	451	501	551	601	651	701	751	801	851	901	951	1001
7	3	7	6	3	15	14	17	20	18	15	19	15
7	4	6	6	4	16	14	18	20	15	15	20	16
4	4	6	6	5	20	13	19	19	15	14	22	15
4	5	5	7	5	17	16	16	19	17	15	23	15
5	5	5	7	6	16	17	15	18	15	18	21	17
6	6	7	7	6	17	19	14	18	16	17	20	16
6	3	7	9	6	17	16	14	16	17	16	23	17
4	3	8	9	6	19	14	13	17	16	19	25	17
4	2	8	10	7	19	16	16	18	17	23	25	15
5	4	11	12	7	12	17	15	17	15	24	27	16
6	4	11	13	8	13	16	14	18	16	21	26	17
6	3	10	14	9	15	15	15	17	14	20	24	16
6	2	10	12	11	15	14	15	19	15	23	24	16
6	3	9	11	10	14	15	18	17	17	24	22	14
5	3	10	11	11	9	13	19	17	18	26	23	13
5	3	8	11	11	11	13	20	18	18	25	21	16
6	3	8	9	6	11	13	17	16	17	25	20	15
5	3	9	9	5	12	14	18	15	18	24	21	16
5	3	8	9	6	11	15	18	15	16	23	20	15
5	3	6	10	6	12	17	18	16	15	22	20	17
4	3	4	9	6	12	16	18	16	13	21	22	16
4	2	5	7	7	10	16	15	17	14	19	23	17
3	2	3	5	7	8	15	16	18	15	20	22	18
3	2	3	3	8	8	15	15	18	16	21	23	18
3	2	3	3	8	9	12	15	19	14	20	22	19
3	2	2	4	8	10	12	17	18	15	19	22	
2	3	2	3	5	10	11	18	17	14	19	21	
2	3	2	4	5	11	13	19	15	15	16	23	
4	4	2	5	4	8	14	21	13	14	16	23	
4	4	3	5	3	11	16	21	15	16	14	23	
4	4	4	5	5	11	16	19	15	17	16	22	
4	4	4	5	7	10	15	17	16	17	17	21	
5	5	4	5	6	10	13	19	17	15	16	22	
5	5	4	5	8	11	12	20	18	13	17	21	
4	5	6	6	9	9	12	23	16	14	17	20	
4	5	7	5	9	9	14	20	15	14	17	20	
3	5	9	5	6	8	13	22	14	14	17	20	
4	5	10	4	6	10	13	21	15	15	17	17	
5	6	9	4	8	8	13	21	16	16	17	17	
5	6	9	6	8	10	13	21	15	16	19	18	
6	5	9	6	10	12	14	20	13	15	19	16	
6	5	7	6	10	11	16	18	14	16	21	16	
4	5	6	5	11	12	15	21	13	16	22	14	
3	5	5	5	11	11	14	20	15	16	22	13	
2	5	5	4	12	13	14	20	16	17	22	13	
2	5	6	4	13	15	17	20	17	17	21	13	
2	5	6	6	10	15	19	20	18	16	22	14	
3	6	6	4	13	12	17	19	17	17	19	15	
2	6	7	5	14	13	15	20	17	18	19	16	
2	6	5	4	15	15	17	20	16	17	19	14	

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EVENT 7
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NUMBER OF SENSORS WITH SIGNAL LESS THAN NOISE AT GIVEN FREQUENCY INDEX

	1	51	101	151	201	251	301	351	401	451	501	551	601	651	701
1	56	0	0	0	4	16	41	47	63	63	48	54	65	46	35
2	56	0	0	0	3	16	40	48	63	64	50	53	61	45	34
3	57	0	0	0	3	16	41	51	62	64	51	52	61	43	35
4	57	0	0	0	5	15	41	52	59	63	52	50	64	45	36
5	56	0	0	0	5	14	41	53	57	62	52	51	66	45	37
6	57	0	0	0	5	14	45	53	54	58	53	53	67	44	37
7	55	0	0	0	7	15	48	54	56	56	55	52	67	41	37
8	58	0	0	0	7	17	48	52	55	52	51	53	65	42	38
9	60	0	0	0	6	21	47	52	54	51	50	51	67	44	35
10	60	0	0	0	5	21	47	50	53	50	51	54	64	47	34
11	62	0	0	0	5	22	48	51	51	51	52	58	62	46	34
12	63	0	0	0	6	23	49	50	52	51	52	59	62	46	35
13	63	0	0	0	6	21	48	48	56	52	52	55	60	47	36
14	65	0	0	0	5	22	49	46	59	53	53	56	57	46	33
15	66	0	0	0	6	25	49	46	59	53	53	54	56	44	34
16	69	0	0	0	5	29	49	49	59	54	55	54	55	45	31
17	69	0	0	0	5	32	48	51	59	52	55	54	55	45	30
18	69	0	0	0	4	32	48	51	58	53	57	54	56	45	26
19	68	0	0	0	2	33	48	47	59	55	55	53	56	47	25
20	65	0	0	0	2	34	45	47	60	55	59	53	58	45	24
21	64	0	0	1	2	34	44	49	58	55	60	54	59	44	25
22	62	0	1	1	1	33	46	47	60	51	57	57	59	44	24
23	60	0	1	1	2	34	46	50	58	52	61	54	59	44	25
24	57	0	1	1	2	34	43	53	57	52	61	54	60	43	27
25	53	0	2	1	2	35	41	55	56	52	61	56	58	42	29
26	51	0	3	1	2	35	46	54	57	52	57	55	56	45	29
27	46	0	3	3	3	36	44	55	59	50	56	54	58	47	29
28	40	0	3	4	3	33	43	56	59	50	54	54	55	45	28
29	35	0	4	4	3	34	43	55	59	52	54	55	55	46	28
30	29	0	4	3	3	31	41	54	60	55	54	57	56	48	30
31	19	0	4	3	3	34	43	56	58	55	55	58	59	48	34
32	14	0	4	2	2	35	42	57	60	55	59	58	59	47	33
33	8	0	3	2	2	35	45	52	59	58	58	58	57	44	35
34	6	0	2	3	1	38	44	53	60	55	60	57	55	45	33
35	4	0	4	3	2	37	43	57	55	53	55	59	52	45	30
36	1	0	3	3	3	35	45	56	55	51	55	57	52	42	29
37	0	0	3	3	5	35	42	54	54	51	56	58	51	43	32
38	0	0	2	3	6	35	39	55	55	51	57	60	51	44	32
39	0	0	2	2	6	36	39	53	57	51	55	59	50	45	34
40	0	0	2	2	6	37	40	57	56	50	55	60	50	41	34
41	0	0	2	2	6	37	40	56	56	49	54	62	46	41	36
42	0	1	2	2	6	31	41	59	57	52	57	62	44	43	35
43	0	1	2	2	10	32	42	58	58	52	57	62	45	40	34
44	0	0	2	2	12	33	44	57	58	51	57	64	45	39	35
45	0	0	2	2	13	34	46	58	59	50	57	63	45	37	34
46	0	0	1	2	12	35	49	61	65	50	57	66	46	37	35
47	0	0	0	1	13	36	52	60	65	52	58	63	46	37	35
48	0	0	0	1	15	36	48	60	66	49	58	65	46	36	35
49	0	0	0	2	14	39	49	62	66	53	57	64	47	35	35
50	0	0	0	3	14	40	48	63	64	51	55	64	47	32	36

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GIVEN FREQUENCY INDEX

401	451	501	551	601	651	701	751	801	851	901	951	1001
63	63	48	54	65	46	35	37	29	19	18	17	20
63	64	50	53	61	45	34	36	27	20	18	17	20
62	64	51	52	61	43	35	34	27	19	17	17	20
59	63	52	50	64	45	36	36	28	21	18	20	18
57	62	52	51	66	45	37	38	30	20	21	16	16
54	58	53	53	67	44	37	35	27	17	20	16	17
56	56	55	52	67	41	37	35	29	19	18	13	17
55	52	51	53	65	42	38	34	29	20	18	13	17
54	51	50	51	67	44	35	36	28	20	17	13	17
53	50	51	54	64	47	34	36	27	20	17	15	18
51	51	52	58	62	46	34	37	28	19	18	16	19
52	51	52	59	62	46	35	34	31	21	18	18	19
56	52	52	55	60	47	36	35	32	21	17	23	17
59	53	53	56	57	46	33	33	30	22	17	26	17
59	53	53	54	56	44	34	36	31	19	18	24	17
59	54	55	54	55	45	31	35	36	19	18	23	16
59	52	55	54	55	45	30	36	35	18	18	22	16
58	53	57	54	56	45	26	39	39	16	19	19	16
59	55	55	53	56	47	25	38	41	17	20	21	17
60	55	59	53	58	45	24	33	35	18	19	22	19
58	55	60	54	59	44	25	34	36	19	20	22	21
60	51	57	57	59	44	24	32	37	21	21	20	23
58	52	61	54	59	44	25	28	37	19	21	18	25
57	52	61	54	60	43	27	29	33	19	17	19	27
56	52	61	56	58	42	29	28	29	18	18	15	28
57	52	57	55	56	45	29	29	27	18	16	16	
59	50	56	54	58	47	29	32	26	20	14	18	
59	50	54	54	55	45	28	31	25	22	13	17	
59	52	54	55	55	46	28	31	22	23	15	15	
60	55	54	57	56	48	30	30	20	22	15	16	
58	55	55	58	59	48	34	30	21	23	14	17	
60	55	59	58	59	47	33	28	21	23	14	17	
59	58	58	58	57	44	35	27	18	21	17	15	
60	55	60	57	55	45	33	30	21	22	18	16	
55	53	55	59	52	45	30	33	20	19	18	15	
55	51	55	57	52	42	29	32	21	16	16	14	
54	51	56	58	51	43	32	30	22	16	15	12	
55	51	57	60	51	44	32	32	21	16	14	10	
57	51	55	59	50	45	34	29	23	16	12	10	
56	50	55	60	50	41	34	30	24	14	14	9	
56	49	54	62	46	41	36	29	27	12	14	12	
57	52	57	62	44	43	35	27	26	15	15	14	
58	52	57	62	45	40	34	28	26	15	15	15	
58	51	57	64	45	39	35	28	27	16	14	16	
59	50	57	63	45	37	34	27	23	15	14	17	
65	50	57	66	46	37	35	26	22	15	16	19	
65	52	58	63	46	37	35	29	22	14	14	17	
66	49	58	65	46	36	35	32	17	15	13	17	
66	53	57	64	47	35	35	33	16	15	14	21	
64	51	55	64	47	32	36	30	18	18	15	19	

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NUMBER OF SENSORS WITH SIGNAL LESS THAN NOISE AT GIVEN FREQUENCY INDEX

	1	51	101	151	201	251	301	351	401	451	501	551	601	651	701
1	45	19	0	0	0	0	0	1	2	0	0	2	2	2	7
2	45	20	0	0	0	0	1	1	2	0	1	3	1	3	6
3	43	20	0	0	0	0	0	1	2	0	1	3	0	3	4
4	46	19	0	0	0	0	0	1	2	0	0	2	1	2	3
5	46	20	0	0	0	0	0	1	2	0	0	4	1	2	3
6	47	17	0	0	0	0	0	0	2	0	1	4	1	2	4
7	47	21	1	0	0	0	0	1	1	0	1	4	0	2	3
8	46	21	0	0	0	0	0	0	1	0	1	3	0	3	3
9	45	21	0	0	0	0	0	0	1	0	1	3	1	4	4
10	44	20	0	0	0	0	0	0	1	0	1	2	1	2	3
11	43	20	0	0	0	0	0	1	2	1	2	1	0	3	4
12	39	19	0	0	0	0	0	1	2	1	2	2	1	3	4
13	38	19	0	0	0	0	0	1	2	0	2	2	2	3	3
14	37	19	0	0	0	0	0	1	1	0	2	1	2	3	4
15	36	20	0	0	0	0	0	1	1	0	2	1	2	4	3
16	38	17	0	0	0	0	1	0	1	0	2	1	0	4	3
17	39	16	0	0	0	0	0	0	2	0	1	1	0	5	3
18	39	15	0	0	0	0	0	0	2	0	1	1	0	4	2
19	38	15	0	0	0	0	0	0	1	0	1	2	1	5	1
20	37	14	0	0	0	0	0	0	1	0	1	3	1	5	2
21	38	12	1	0	0	0	0	1	1	0	3	3	2	6	2
22	38	10	1	0	0	0	0	1	1	0	3	4	2	5	4
23	39	7	3	0	0	0	0	1	0	0	4	4	2	4	4
24	38	6	3	0	0	0	0	1	0	0	5	3	2	4	4
25	40	5	3	0	0	0	0	1	0	0	7	3	3	4	4
26	44	5	2	0	0	0	0	1	0	0	6	1	4	5	4
27	45	5	1	0	0	0	0	1	0	0	5	0	4	5	5
28	46	3	0	0	0	0	0	1	0	0	6	0	3	5	5
29	44	3	0	1	0	0	0	1	0	0	6	1	4	5	6
30	46	4	0	1	0	0	0	0	0	0	6	1	4	3	5
31	45	3	0	0	0	0	0	1	0	0	4	2	3	2	7
32	46	3	0	0	0	0	0	1	0	1	5	3	3	3	10
33	46	3	0	0	0	0	0	0	0	2	3	3	2	4	9
34	48	3	0	0	0	0	0	0	2	2	3	3	2	4	7
35	46	3	0	0	0	0	0	0	3	2	2	2	2	4	10
36	47	3	0	0	0	0	0	1	1	1	1	2	3	3	10
37	46	2	0	0	0	0	0	1	0	1	1	2	3	3	10
38	43	2	0	0	0	0	0	1	0	2	1	2	3	5	10
39	44	2	0	0	0	0	0	1	0	1	1	5	2	5	12
40	41	2	0	0	0	0	0	0	2	1	1	5	1	4	13
41	35	2	0	0	0	0	0	0	2	0	1	5	1	3	11
42	33	2	0	0	0	0	0	0	2	0	0	4	1	3	10
43	34	1	0	0	0	0	0	0	2	1	1	4	1	3	9
44	33	1	0	0	0	0	0	0	2	1	0	4	2	3	9
45	29	1	0	0	0	0	1	0	1	1	0	4	2	4	8
46	29	1	0	0	0	0	1	0	1	1	0	2	3	4	7
47	29	1	0	0	0	0	1	1	1	1	0	2	4	4	7
48	26	0	0	0	0	0	1	1	1	1	1	1	4	5	7
49	26	0	0	0	0	0	1	1	1	0	1	1	3	5	7
50	23	0	0	0	0	0	1	2	1	0	1	2	3	6	5

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AT GIVEN FREQUENCY INDEX

401	451	501	551	601	651	701	751	801	851	901	951	1001
2	0	0	2	2	2	7	7	2	8	6	3	5
2	0	1	3	1	3	6	7	3	8	6	2	5
2	0	1	3	0	3	4	5	3	7	6	2	5
2	0	0	2	1	2	3	5	3	6	4	2	5
2	0	0	4	1	2	3	5	4	6	3	2	6
2	0	1	4	1	2	4	6	4	6	3	3	5
1	0	1	4	0	2	3	6	4	5	4	3	5
1	0	1	3	0	3	3	5	4	6	6	3	3
1	0	1	3	1	4	4	6	2	4	5	3	2
1	0	1	2	1	2	3	5	2	4	5	3	2
2	1	2	1	0	3	4	6	2	5	5	5	2
2	1	2	2	1	3	4	6	2	5	5	6	3
2	0	2	2	2	3	3	4	2	3	4	5	2
1	0	2	1	2	3	4	4	1	4	3	4	2
1	0	2	1	2	4	3	4	2	4	2	4	1
1	0	2	1	0	4	3	5	4	4	2	6	1
2	0	1	1	0	5	3	5	4	4	3	5	2
2	0	1	1	0	4	2	4	4	5	4	5	2
1	0	1	2	1	5	1	3	5	4	4	5	5
1	0	1	3	1	5	2	2	5	4	4	5	6
1	0	3	3	2	6	2	3	5	5	3	6	6
1	0	3	4	2	5	4	3	6	8	3	6	7
0	0	4	4	2	4	4	3	8	7	4	7	8
0	0	5	3	2	4	4	4	7	6	4	5	9
0	0	7	3	3	4	4	3	6	6	3	4	9
0	0	6	1	4	5	4	1	7	5	2	4	
0	0	5	0	4	5	5	2	6	5	2	4	
0	0	6	0	3	5	5	2	6	5	3	3	
0	0	6	1	4	5	6	1	5	2	4	4	
0	0	6	1	4	3	5	1	4	2	3	4	
0	0	4	2	3	2	7	1	4	3	3	3	
0	1	5	3	3	3	10	1	4	2	3	4	
0	2	3	3	2	4	9	1	4	3	4	4	
2	2	3	3	2	4	7	1	4	3	5	4	
3	2	2	2	2	4	10	1	4	2	5	5	
1	1	1	2	3	3	10	2	3	1	4	6	
0	1	1	2	3	3	10	2	3	2	4	7	
0	2	1	2	3	5	10	3	3	2	4	6	
0	1	1	5	2	5	12	3	3	2	4	6	
2	1	1	5	1	4	13	2	4	2	5	6	
2	0	1	5	1	3	11	0	4	2	6	5	
2	0	0	4	1	3	10	1	5	1	6	4	
2	1	1	4	1	3	9	2	8	4	5	4	
2	1	0	4	2	3	9	3	8	3	4	4	
1	1	0	4	2	4	8	3	7	3	4	5	
1	1	0	2	3	4	7	5	6	3	5	5	
1	1	0	2	4	4	7	4	6	4	4	6	
1	1	1	1	4	5	7	3	6	5	2	4	
1	0	1	1	3	5	7	2	6	6	2	6	
1	0	1	2	3	6	5	2	8	6	2	7	

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NUMBER OF SENSORS WITH SIGNAL LESS THAN NOISE AT GIVEN FREQUENCY INDEX

	1	51	101	151	201	251	301	351	401	451	501	551	601	651	701
1	62	4	26	0	0	1	3	5	18	23	34	29	40	33	24
2	62	3	23	0	1	1	8	5	17	25	34	29	40	34	25
3	60	0	23	0	1	1	11	6	17	25	30	29	43	32	25
4	59	0	20	0	1	2	10	7	17	26	31	30	43	30	26
5	59	0	20	0	1	2	12	8	15	29	33	33	40	30	26
6	58	0	20	0	1	2	12	8	16	27	33	37	38	28	26
7	58	0	21	0	1	2	12	8	17	25	36	39	39	26	27
8	59	0	26	0	1	2	11	8	19	27	37	38	35	28	24
9	60	0	36	0	1	2	8	6	17	28	35	37	36	27	22
10	59	0	45	0	1	2	9	6	19	25	36	38	37	28	24
11	60	0	48	0	1	3	8	7	21	26	37	41	36	28	22
12	60	0	41	0	1	3	8	6	23	25	38	42	33	29	22
13	60	0	31	0	1	3	7	6	24	29	38	43	33	29	22
14	57	0	24	0	2	3	7	10	30	30	36	43	32	28	27
15	58	0	19	0	1	4	8	9	31	31	36	44	30	28	22
16	59	0	14	0	1	5	9	10	34	34	34	45	30	27	22
17	58	0	7	0	0	4	9	11	33	34	35	43	28	27	24
18	58	0	5	0	1	5	6	10	34	34	35	43	30	28	23
19	58	0	3	0	1	5	5	8	33	34	34	46	31	29	21
20	58	0	1	1	2	7	5	9	31	34	36	43	30	29	22
21	58	0	1	1	3	11	8	10	30	33	36	42	31	29	23
22	60	0	1	1	3	13	9	8	27	34	34	39	29	29	24
23	60	0	1	1	3	15	10	10	28	31	34	38	30	25	25
24	57	1	1	1	3	15	9	8	26	31	35	38	30	23	27
25	59	1	1	1	3	15	12	9	25	32	36	41	31	23	28
26	60	0	1	1	3	14	11	7	23	30	36	40	31	22	28
27	59	0	1	1	4	15	13	8	21	32	35	40	30	23	25
28	51	1	0	1	3	11	12	10	22	32	36	42	30	24	23
29	48	1	0	0	5	9	12	12	25	31	37	42	26	26	25
30	47	1	0	0	6	7	12	13	23	33	36	40	26	27	27
31	46	1	0	0	9	7	11	14	24	34	37	40	26	27	29
32	47	2	0	0	10	8	9	13	24	33	37	38	25	25	26
33	47	4	0	0	12	6	9	13	27	32	35	35	28	24	25
34	45	6	0	0	16	4	8	14	28	29	36	37	29	22	25
35	45	8	0	0	24	3	8	13	28	25	36	38	26	22	24
36	47	8	0	0	22	4	10	15	27	23	37	40	30	21	25
37	48	9	0	0	23	4	11	16	26	25	34	39	31	22	25
38	50	12	0	0	25	4	11	15	28	26	36	38	31	21	26
39	47	14	0	0	16	4	9	15	28	25	38	39	32	20	23
40	45	14	0	0	11	3	9	16	30	24	37	35	30	20	22
41	39	15	0	0	9	2	10	15	32	27	36	37	33	19	21
42	37	19	0	0	6	2	9	15	32	30	33	39	33	20	21
43	32	21	0	0	5	3	7	16	32	32	34	40	33	20	20
44	30	25	0	1	2	3	8	20	32	32	33	39	33	23	21
45	26	25	0	0	2	3	7	21	33	34	31	39	28	21	22
46	21	28	0	1	1	3	4	20	32	34	33	40	29	22	23
47	16	32	0	1	0	3	5	20	30	35	34	37	30	26	25
48	14	36	0	1	0	3	6	19	28	36	31	37	33	26	26
49	8	38	0	1	1	3	5	16	25	37	30	38	33	24	28
50	6	32	0	1	1	3	5	16	25	34	30	39	33	24	28

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GIVEN FREQUENCY INDEX

401	451	501	551	601	651	701	751	801	851	901	951	1001
18	23	34	29	40	33	24	25	20	16	15	22	20
17	25	34	29	40	34	25	30	22	18	16	22	19
17	25	30	29	43	32	25	31	23	20	16	22	18
17	26	31	30	43	30	26	30	23	21	16	22	18
15	29	33	33	40	30	26	29	23	22	17	22	20
16	27	33	37	38	28	26	32	23	22	15	23	20
17	25	36	39	39	26	27	31	20	21	15	24	22
19	27	37	38	35	28	24	31	21	23	15	24	23
17	28	35	37	36	27	22	29	26	20	16	25	21
19	25	36	38	37	28	24	25	21	21	17	21	24
21	26	37	41	36	28	22	26	22	23	17	19	23
23	25	38	42	33	29	22	22	23	24	17	17	22
24	29	38	43	33	29	22	20	24	24	15	17	23
30	30	36	43	32	28	27	21	21	22	13	16	23
31	31	36	44	30	28	22	20	22	18	13	13	23
34	34	34	45	30	27	22	21	20	16	15	13	19
33	34	35	43	28	27	24	20	19	16	14	13	17
34	34	35	43	30	28	23	19	20	13	17	17	21
33	34	34	46	31	29	21	21	20	13	17	18	23
31	34	36	43	30	29	22	21	18	15	18	17	24
30	33	36	42	31	29	23	21	19	18	19	17	22
27	34	34	39	29	29	24	20	18	17	18	18	24
28	31	34	38	30	25	25	22	20	16	17	18	25
26	31	35	38	30	23	27	22	18	17	17	16	26
25	32	36	41	31	23	28	25	18	16	17	16	26
23	30	36	40	31	22	28	25	17	14	17	18	
21	32	35	40	30	23	25	26	15	14	17	18	
22	32	36	42	30	24	23	23	16	15	16	18	
25	31	37	42	26	26	25	25	16	15	16	18	
23	33	36	40	26	27	27	26	17	16	17	17	
24	34	37	40	26	27	29	27	17	16	17	11	
24	33	37	38	25	25	26	28	16	16	14	11	
27	32	35	35	28	24	25	27	18	17	17	11	
28	29	36	37	29	22	25	27	15	17	16	11	
28	25	36	38	26	22	24	24	16	19	17	13	
27	23	37	40	30	21	25	25	19	17	17	14	
26	25	34	39	31	22	25	23	17	16	15	13	
28	26	36	38	31	21	26	21	17	16	14	14	
28	25	38	39	32	20	23	20	17	18	14	14	
30	24	37	35	30	20	22	21	16	19	16	14	
32	27	36	37	33	19	21	21	16	16	17	17	
32	30	33	39	33	20	21	22	16	15	18	16	
32	32	34	40	33	20	20	23	13	11	19	17	
32	32	33	39	33	23	21	23	13	12	20	17	
33	34	31	39	28	21	22	24	11	12	20	16	
32	34	33	40	29	22	23	22	12	13	19	19	
30	35	34	37	30	26	25	23	14	12	17	20	
28	36	31	37	33	26	26	20	15	12	17	21	
25	37	30	38	33	24	28	21	15	14	18	22	
25	34	30	39	33	24	28	20	15	15	19	23	

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NUMBER OF SENSORS WITH SIGNAL LESS THAN NOISE AT GIVEN FREQUENCY INDEX

	1	51	101	151	201	251	301	351	401	451	501	551	601	651	701
1	62	2	7	1	55	46	49	49	51	50	60	60	48	55	46
2	62	2	7	1	54	46	47	46	52	53	64	58	48	53	41
3	62	2	7	1	57	44	47	41	52	53	62	59	48	53	38
4	60	1	9	1	54	44	45	42	48	54	63	58	50	54	37
5	58	1	11	1	52	47	47	46	50	56	61	59	52	52	36
6	58	0	15	0	47	47	51	49	50	56	64	60	51	56	33
7	56	0	22	0	45	47	54	48	47	57	61	58	53	55	36
8	56	0	22	0	41	43	53	49	45	58	59	59	52	54	32
9	56	0	22	0	38	39	50	51	45	59	63	59	52	53	34
10	55	0	23	0	35	43	52	53	46	59	63	59	51	52	34
11	55	0	23	0	33	46	53	53	44	58	61	61	54	51	30
12	55	0	18	0	32	47	52	54	47	57	59	60	54	54	32
13	53	0	16	0	31	47	51	55	48	56	60	61	52	51	29
14	50	0	15	0	32	47	49	53	50	55	57	62	53	55	29
15	50	0	15	0	34	46	49	55	48	54	56	63	56	55	28
16	49	0	12	0	33	46	50	53	50	58	59	63	54	53	29
17	47	0	11	0	33	45	49	52	53	57	60	64	55	53	29
18	45	0	7	0	31	47	46	54	56	59	59	64	55	53	29
19	45	0	5	0	31	45	46	56	56	59	59	60	56	52	29
20	46	0	5	0	30	44	45	56	60	58	60	57	54	53	29
21	45	0	4	0	30	46	47	57	63	58	60	54	57	54	31
22	42	0	5	1	28	49	46	55	63	58	59	53	56	51	31
23	42	0	3	1	27	48	45	57	64	58	59	54	55	51	34
24	44	0	5	2	26	50	48	56	64	62	62	55	51	46	31
25	43	0	6	2	26	51	50	60	66	60	59	53	51	47	35
26	45	0	5	2	29	53	51	61	68	60	58	52	49	47	33
27	45	0	4	2	32	55	53	62	66	62	57	51	51	48	35
28	49	0	4	3	34	53	54	60	64	60	57	48	50	49	35
29	50	0	5	3	33	57	53	64	66	58	54	50	55	49	35
30	49	0	5	4	33	58	52	64	66	60	52	50	54	50	34
31	50	0	3	5	34	62	55	62	68	61	52	52	54	49	32
32	48	0	3	5	34	62	53	62	69	64	52	51	54	48	33
33	49	0	2	6	35	60	54	67	65	63	53	49	52	47	36
34	48	0	0	8	37	60	55	67	65	63	52	48	55	44	35
35	45	0	0	10	39	56	59	63	62	60	52	50	53	46	32
36	44	0	0	11	40	56	57	61	63	61	51	50	51	46	32
37	44	0	0	13	42	54	56	61	64	59	53	52	51	50	34
38	39	0	0	15	41	55	53	58	59	55	55	54	54	47	35
39	37	0	0	16	40	56	51	57	58	56	56	57	54	49	36
40	32	0	0	17	38	53	52	57	59	57	59	57	56	47	38
41	24	1	0	19	40	49	53	56	63	58	60	59	57	46	33
42	23	1	0	27	40	45	50	52	62	58	58	60	58	48	30
43	20	1	1	29	41	45	52	50	64	60	59	63	57	47	32
44	17	1	1	37	40	45	53	49	65	56	61	60	58	47	29
45	17	1	0	37	38	50	54	51	62	55	59	61	56	46	29
46	14	1	0	42	39	51	59	54	64	56	58	61	55	48	29
47	8	3	1	44	42	51	57	52	63	55	58	56	57	49	30
48	8	3	1	49	42	51	53	48	61	57	60	52	52	49	29
49	5	5	1	53	43	46	54	47	53	59	59	51	51	46	27
50	4	6	1	53	47	49	52	50	51	60	61	48	54	45	25

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IVEN FREQUENCY INDEX

01	451	501	551	601	651	701	751	801	851	901	951	1001
51	50	60	60	48	55	46	26	32	33	31	17	28
52	53	64	58	48	53	41	29	32	36	34	17	30
52	53	62	59	48	53	38	31	31	36	34	20	31
48	54	63	58	50	54	37	34	31	35	33	19	32
50	56	61	59	52	52	36	34	34	32	33	19	30
50	56	64	60	51	56	33	35	38	34	33	18	30
47	57	61	58	53	55	36	32	37	31	32	21	32
45	58	59	59	52	54	32	33	37	28	33	19	31
45	59	63	59	52	53	34	34	35	30	35	19	32
46	59	63	59	51	52	34	33	35	29	33	20	30
44	58	61	61	54	51	30	33	34	25	36	22	30
47	57	59	60	54	54	32	33	38	25	35	22	33
48	56	60	61	52	51	29	36	37	23	34	22	33
50	55	57	62	53	55	29	37	33	26	35	23	32
48	54	56	63	56	55	28	38	32	29	35	22	32
50	58	59	63	54	53	29	40	31	26	34	21	29
53	57	60	64	55	53	29	39	30	26	33	23	33
56	59	59	64	55	53	29	41	29	27	34	24	34
56	59	59	60	56	52	29	40	27	26	32	21	35
60	58	60	57	54	53	29	34	24	27	32	21	35
63	58	60	54	57	54	31	36	24	23	32	24	35
63	58	59	53	56	51	31	38	29	25	29	27	33
64	58	59	54	55	51	34	39	27	26	29	31	35
64	62	62	55	51	46	31	36	24	27	29	29	36
66	60	59	53	51	47	35	37	24	27	29	29	36
68	60	58	52	49	47	33	37	26	27	32	27	
66	62	57	51	51	48	35	35	26	27	31	29	
64	60	57	48	50	49	35	37	24	29	32	29	
66	58	54	50	55	49	35	40	24	30	31	30	
66	60	52	50	54	50	34	39	24	28	33	30	
68	61	52	52	54	49	32	37	25	26	35	31	
69	64	52	51	54	48	33	36	22	26	35	29	
65	63	53	49	52	47	36	36	22	26	33	32	
65	63	52	48	55	44	35	37	19	28	34	33	
62	60	52	50	53	46	32	38	20	27	31	32	
63	61	51	50	51	46	32	38	22	28	30	34	
64	59	53	52	51	50	34	37	24	25	29	36	
59	55	55	54	54	47	35	39	27	26	30	39	
58	56	56	57	54	49	36	39	26	27	28	38	
59	57	59	57	56	47	38	39	30	27	28	37	
63	58	60	59	57	46	33	38	29	26	21	34	
62	58	58	60	58	48	30	40	29	28	20	34	
64	60	59	63	57	47	32	37	30	28	19	33	
65	56	61	60	58	47	29	36	28	30	16	32	
62	55	59	61	56	46	29	36	28	28	18	32	
64	56	58	61	55	48	29	36	28	31	17	29	
63	55	58	56	57	49	30	34	31	35	16	30	
61	57	60	52	52	49	29	33	34	35	17	30	
53	59	59	51	51	46	27	33	35	31	18	30	
51	60	61	48	54	45	25	34	35	32	19	29	

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NUMBER OF SENSORS WITH SIGNAL LESS THAN NOISE AT GIVEN FREQUENCY INDEX

	1	51	101	151	201	251	301	351	401	451	501	551	601	651	701
1	18	14	19	1	0	1	1	1	1	2	2	4	4	2	11
2	18	15	17	1	0	1	1	1	1	2	1	5	4	2	10
3	18	16	17	2	0	1	1	1	1	3	1	5	4	2	9
4	18	18	19	2	0	2	1	1	1	3	1	4	3	2	8
5	18	17	17	1	0	2	1	1	1	5	1	2	4	3	7
6	20	20	19	1	0	2	1	1	1	5	1	3	4	3	7
7	21	20	19	1	0	2	1	2	1	5	1	3	2	3	7
8	21	20	19	1	0	3	1	2	1	6	1	3	2	3	8
9	23	19	19	1	0	4	1	2	1	6	2	2	2	4	7
10	24	20	16	1	0	5	1	2	2	7	2	3	3	5	7
11	24	22	15	1	0	5	0	2	2	7	3	2	2	6	8
12	24	20	15	1	0	5	0	2	3	7	3	2	2	6	8
13	23	19	14	2	0	4	0	1	3	5	3	1	2	6	9
14	21	19	13	2	0	4	0	1	3	5	5	2	1	6	9
15	22	18	13	2	0	3	0	3	3	5	5	1	1	6	10
16	22	18	12	2	0	2	0	4	2	6	5	2	2	6	10
17	22	18	13	3	0	1	0	4	2	6	5	2	2	6	9
18	23	20	13	3	0	1	0	3	2	6	4	4	2	6	9
19	23	22	12	3	0	1	0	4	2	7	5	4	4	6	10
20	24	22	13	3	0	2	0	1	2	7	5	6	4	4	9
21	23	21	13	3	0	1	0	2	1	6	4	7	5	4	8
22	23	20	14	2	0	2	0	2	1	6	5	8	4	4	8
23	23	20	13	2	0	3	0	4	1	6	5	8	4	4	7
24	23	20	11	2	0	2	1	4	1	7	5	9	3	4	7
25	24	19	11	2	1	2	1	4	1	7	4	10	3	4	7
26	23	19	10	1	1	3	1	4	1	6	4	7	3	4	7
27	23	19	9	2	1	4	1	4	1	5	5	6	4	4	6
28	23	19	9	2	1	4	0	4	1	4	6	6	3	5	6
29	22	19	5	1	1	4	0	4	1	4	6	6	3	5	8
30	23	18	4	1	1	3	0	4	3	5	6	5	3	6	8
31	24	19	4	1	1	3	0	4	4	4	5	6	3	7	7
32	23	19	4	0	1	2	0	4	4	3	6	6	5	7	7
33	22	19	4	0	1	2	0	4	4	3	7	6	5	7	8
34	22	20	4	0	1	1	0	2	3	3	7	5	4	7	7
35	18	21	3	0	1	1	0	2	3	3	6	4	5	7	6
36	19	23	2	0	1	1	0	2	2	4	6	4	5	7	6
37	17	24	2	0	0	1	0	3	2	4	5	4	5	6	6
38	18	24	1	0	0	1	0	2	2	4	5	4	4	8	6
39	19	24	1	0	0	1	1	2	2	4	4	3	4	9	6
40	21	23	1	0	0	1	1	2	2	2	3	3	3	10	6
41	23	24	1	0	0	1	1	2	2	2	3	3	1	9	8
42	22	24	1	0	0	1	1	2	2	2	3	3	2	10	8
43	20	23	2	0	0	1	1	2	2	2	2	3	3	9	7
44	20	22	2	0	0	1	1	2	2	2	2	3	4	10	9
45	18	21	2	0	0	0	1	2	1	2	2	3	3	10	9
46	19	20	1	0	0	1	1	1	2	2	2	3	2	10	9
47	18	20	1	0	0	1	1	1	3	2	2	3	2	10	9
48	17	20	1	0	0	1	1	1	3	2	2	3	2	11	8
49	17	20	1	0	0	1	1	1	2	3	4	3	2	11	8
50	16	18	1	0	1	1	1	1	2	3	4	4	2	11	8

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VEN FREQUENCY INDEX

01	451	501	551	601	651	701	751	801	851	901	951	1001
1	2	2	4	4	2	11	10	7	9	13	16	13
1	2	1	5	4	2	10	11	7	11	13	15	16
1	3	1	5	4	2	9	11	7	9	13	14	16
1	3	1	4	3	2	8	11	7	9	13	13	16
1	5	1	2	4	3	7	11	7	12	12	10	15
1	5	1	3	4	3	7	10	9	12	11	10	17
1	5	1	3	2	3	7	9	8	12	12	12	15
1	6	1	3	2	3	8	8	9	12	12	12	15
1	6	2	2	2	4	7	8	9	11	14	11	14
2	7	2	3	3	5	7	9	9	12	14	13	14
2	7	3	2	2	6	8	7	9	12	14	14	14
3	7	3	2	2	6	8	4	10	11	14	15	14
3	5	3	1	2	6	9	4	10	11	14	14	14
3	5	5	2	1	6	9	5	10	11	14	14	14
3	5	5	1	1	6	10	6	10	13	14	16	14
2	6	5	2	2	6	10	5	11	14	13	16	14
2	6	5	2	2	6	9	5	10	14	13	15	15
2	6	4	4	2	6	9	5	10	16	13	15	15
2	7	5	4	4	6	10	4	11	15	15	16	18
2	7	5	6	4	4	9	4	13	12	14	16	18
1	6	4	7	5	4	8	5	13	12	16	16	18
1	6	5	8	4	4	8	6	13	12	17	16	19
1	6	5	8	4	4	7	7	13	14	20	15	19
1	7	5	9	3	4	7	6	14	15	20	15	17
1	7	4	10	3	4	7	9	12	16	21	17	16
1	6	4	7	3	4	7	9	9	17	18	18	
1	5	5	6	4	4	6	8	11	17	19	19	
1	4	6	6	3	5	6	9	9	16	19	19	
1	4	6	6	3	5	8	10	10	15	20	19	
3	5	6	5	3	6	8	8	12	15	19	18	
4	4	5	6	3	7	7	8	12	16	20	18	
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4	3	7	6	5	7	8	8	11	17	18	17	
3	3	7	5	4	7	7	8	13	17	17	15	
3	3	6	4	5	7	6	9	12	18	17	15	
2	4	6	4	5	7	6	9	12	16	16	15	
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2	3	4	3	2	11	8	6	8	12	16	13	
2	3	4	4	2	11	8	6	9	13	14	13	

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NUMBER OF SENSORS WITH SIGNAL LESS THAN NOISE AT GIVEN FREQUENCY INDEX

	1	51	101	151	201	251	301	351	401	451	501	551	601	651	701
1	14	18	21	13	21	2	16	10	21	13	22	19	19	17	17
2	14	19	20	13	21	3	17	10	21	14	19	17	20	16	16
3	14	19	19	14	21	4	17	9	20	13	18	15	20	16	15
4	14	20	18	13	20	4	18	8	21	14	20	14	20	17	16
5	14	20	16	14	19	4	20	8	18	13	20	16	19	18	16
6	15	19	13	15	19	4	19	10	15	11	18	17	19	18	15
7	15	20	12	18	17	3	19	12	17	12	19	17	18	17	14
8	15	18	10	19	17	3	18	12	17	13	20	17	20	17	16
9	15	19	10	19	13	3	18	13	17	13	20	19	20	15	16
10	15	20	9	18	12	3	17	14	19	14	20	20	19	13	16
11	12	20	9	18	12	3	17	14	18	14	19	20	18	14	15
12	12	21	8	20	11	3	16	13	19	14	20	19	20	15	14
13	11	19	7	19	11	4	15	13	18	14	20	19	20	14	16
14	11	19	7	18	9	3	18	12	19	15	20	18	19	14	17
15	10	19	6	17	9	2	18	13	18	16	18	17	19	12	17
16	8	19	5	13	9	2	20	13	17	16	18	17	19	12	19
17	8	17	5	14	7	2	18	13	17	17	17	17	19	12	20
18	11	17	5	15	7	2	18	13	18	19	17	16	16	14	19
19	10	17	4	15	6	3	19	13	20	20	19	14	15	14	18
20	12	21	4	15	5	5	18	13	18	20	19	15	15	15	19
21	14	24	4	15	4	7	18	14	17	21	18	14	15	15	19
22	14	24	3	14	4	8	18	14	17	21	18	15	15	15	20
23	15	23	3	13	3	11	19	14	17	21	19	16	17	16	21
24	16	23	3	14	3	13	21	15	18	23	20	15	17	16	21
25	16	21	5	15	3	15	22	16	19	21	21	13	18	16	21
26	16	19	6	16	3	16	22	17	18	22	20	14	18	14	20
27	14	21	6	16	2	18	21	17	19	23	22	13	17	15	19
28	13	22	6	19	1	18	21	17	20	22	22	13	16	16	18
29	11	26	6	17	1	19	20	17	21	21	20	13	16	15	17
30	12	26	6	17	0	19	20	17	20	20	21	16	15	15	16
31	13	25	6	18	2	20	21	15	19	21	20	15	16	18	18
32	16	24	6	20	3	21	22	18	20	22	19	17	17	19	18
33	16	23	6	18	3	21	20	19	19	21	19	19	19	20	20
34	17	22	6	21	3	20	17	20	18	23	20	18	20	20	22
35	20	22	8	21	3	20	17	20	17	23	20	18	20	19	23
36	20	21	8	21	3	19	17	23	17	21	22	18	21	19	23
37	20	23	9	20	4	20	16	21	18	22	22	20	20	17	23
38	20	24	11	19	4	18	15	22	18	23	23	20	20	16	23
39	23	24	12	18	4	19	16	20	18	22	24	21	20	15	23
40	24	22	10	18	4	19	15	20	18	22	24	18	21	19	21
41	22	23	10	18	6	19	15	19	16	22	24	18	20	18	21
42	23	22	12	17	5	19	16	19	16	21	25	17	20	18	21
43	23	22	12	17	5	19	14	18	16	21	25	16	20	16	21
44	24	22	13	19	5	17	13	19	16	20	25	17	19	17	21
45	21	22	12	19	5	17	14	18	16	20	25	18	19	15	22
46	19	21	12	20	4	18	14	20	12	22	23	19	20	16	24
47	18	20	13	21	3	17	13	19	13	23	22	21	19	16	23
48	16	22	12	22	3	15	13	20	13	23	22	20	18	17	23
49	17	21	12	22	3	13	12	21	12	22	22	19	16	17	23
50	19	21	12	20	3	16	11	22	13	22	21	17	15	17	24

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IVEN FREQUENCY INDEX

01	451	501	551	601	651	701	751	801	851	901	951	1001
21	13	22	19	19	17	17	23	17	16	20	13	20
21	14	19	17	20	16	16	21	16	15	20	15	20
20	13	18	15	20	16	15	20	15	16	20	15	19
21	14	20	14	20	17	16	19	16	17	20	15	21
18	13	20	16	19	18	16	19	17	17	20	17	20
15	11	18	17	19	18	15	18	17	17	19	16	18
17	12	19	17	18	17	14	17	18	18	18	16	18
17	13	20	17	20	17	16	15	18	18	18	15	18
17	13	20	19	20	15	16	18	18	18	17	15	19
19	14	20	20	19	13	16	19	17	19	16	15	19
18	14	19	20	18	14	15	17	18	17	15	16	16
19	14	20	19	20	15	14	18	20	17	16	16	15
18	14	20	19	20	14	16	17	19	18	18	16	18
19	15	20	18	19	14	17	18	18	18	18	17	19
18	16	18	17	19	12	17	18	18	18	18	18	19
17	16	18	17	19	12	19	18	18	16	16	18	18
17	17	17	17	19	12	20	18	17	16	15	17	18
18	19	17	16	16	14	19	19	17	15	14	16	19
20	20	19	14	15	14	18	19	17	15	13	15	19
18	20	19	15	15	15	19	18	17	15	12	17	19
17	21	18	14	15	15	19	18	18	15	14	17	19
17	21	18	15	15	15	20	17	19	15	15	17	19
17	21	19	16	17	16	21	17	20	15	16	18	19
18	23	20	15	17	16	21	18	21	16	17	18	19
19	21	21	13	18	16	21	19	22	16	17	18	19
18	22	20	14	18	14	20	20	20	17	17	19	
19	23	22	13	17	15	19	20	19	17	16	19	
20	22	22	13	16	16	18	20	20	16	17	18	
21	21	20	13	16	15	17	20	20	15	17	20	
20	20	21	16	15	15	16	19	18	16	17	20	
19	21	20	15	16	18	18	19	18	17	18	21	
20	22	19	17	17	19	18	19	17	18	18	20	
19	21	19	19	19	20	20	20	17	17	18	19	
18	23	20	18	20	20	22	20	19	19	17	18	
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16	21	25	16	20	16	21	16	13	21	17	16	
16	20	25	17	19	17	21	15	14	21	18	16	
16	20	25	18	19	15	22	15	16	22	19	18	
12	22	23	19	20	16	24	15	15	22	18	18	
13	23	22	21	19	16	23	16	13	20	17	19	
13	23	22	20	18	17	23	15	14	19	16	19	
12	22	22	19	16	17	23	15	15	19	15	18	
13	22	21	17	15	17	24	14	15	19	14	19	

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NUMBER OF SENSORS WITH SIGNAL LESS THAN NOISE AT GIVEN FREQUENCY INDEX

	1	51	101	151	201	251	301	351	401	451	501	551	601	651	701
1	29	27	16	21	1	10	9	3	0	13	3	12	11	13	21
2	28	27	16	20	1	11	9	3	0	11	4	12	10	12	22
3	28	27	19	15	1	12	8	3	0	11	4	13	9	12	24
4	28	27	21	18	1	13	9	3	0	10	3	11	9	12	24
5	26	26	20	17	1	13	10	3	0	8	4	10	8	10	26
6	26	25	20	14	1	12	10	4	0	8	6	11	8	10	26
7	27	27	19	14	2	11	12	4	0	7	7	10	11	10	25
8	28	28	19	13	2	11	11	5	0	6	7	9	9	11	25
9	27	27	19	11	2	12	8	5	0	6	6	9	9	10	25
10	27	27	20	9	2	11	8	5	0	6	7	10	9	10	25
11	29	26	20	9	2	10	8	5	1	5	6	10	9	11	23
12	29	25	22	9	1	9	8	7	1	5	7	12	7	13	22
13	30	25	23	9	1	9	6	7	1	5	8	15	6	14	20
14	30	28	21	9	1	8	6	7	2	6	8	15	5	15	20
15	28	28	21	9	1	9	6	7	3	6	11	15	6	14	21
16	28	27	23	9	2	9	8	7	3	5	11	17	7	15	20
17	28	27	23	10	3	8	8	7	2	6	12	16	7	17	22
18	28	27	21	10	4	8	7	7	1	6	13	13	7	18	22
19	28	26	24	10	4	7	9	6	3	6	13	12	7	18	23
20	28	25	22	9	5	6	9	5	3	6	13	8	7	18	22
21	29	22	21	9	5	7	8	4	3	7	12	9	7	20	21
22	28	20	19	8	5	8	8	4	4	9	12	9	8	20	21
23	28	20	20	8	4	7	7	3	4	12	11	9	8	20	24
24	30	18	20	7	3	7	8	3	5	12	12	8	7	21	22
25	29	19	20	8	3	7	8	3	6	11	10	8	7	22	22
26	29	17	19	7	3	8	7	3	6	11	7	7	8	21	21
27	28	17	20	6	3	8	8	3	6	11	6	7	8	24	22
28	28	16	21	4	3	9	9	3	6	11	8	8	7	23	22
29	29	15	20	2	2	8	11	3	7	11	9	8	9	23	20
30	29	16	19	2	3	8	11	2	8	11	9	8	9	23	20
31	27	18	20	2	4	8	12	2	8	10	10	10	10	23	18
32	28	18	19	1	4	7	14	2	7	9	10	11	12	25	16
33	26	17	22	1	4	7	13	2	7	10	11	10	13	25	15
34	27	16	21	1	4	8	10	2	7	9	10	12	11	22	17
35	27	20	21	1	4	8	9	2	8	10	10	12	11	22	16
36	26	20	21	0	4	4	6	1	7	9	11	9	10	22	14
37	26	20	20	0	4	5	4	0	7	9	12	9	10	21	15
38	26	20	18	0	4	4	3	3	7	7	11	9	11	21	16
39	27	21	14	0	6	2	3	3	7	8	11	10	10	19	17
40	27	20	15	0	7	2	4	2	7	8	11	11	11	19	16
41	27	20	15	0	8	2	4	1	7	8	11	13	12	18	17
42	28	19	15	0	8	2	3	1	7	8	12	13	12	21	17
43	27	18	16	0	9	2	3	1	9	8	13	13	13	21	18
44	25	18	18	0	9	2	2	1	11	7	13	14	12	21	17
45	25	18	18	0	9	2	2	1	12	7	13	13	13	21	17
46	27	17	19	0	9	3	1	1	14	7	15	13	13	20	16
47	24	19	19	0	10	6	1	1	12	7	16	12	13	20	16
48	26	18	19	0	10	6	0	0	13	4	15	12	12	21	17
49	26	18	21	1	9	7	1	0	12	4	13	13	12	22	16
50	25	18	21	1	9	9	2	1	13	4	13	12	11	22	18

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IVEN FREQUENCY INDEX

01	451	501	551	601	651	701	751	801	851	901	951	1001
0	13	3	12	11	13	21	19	24	23	17	26	27
0	11	4	12	10	12	22	19	24	23	15	27	24
0	11	4	13	9	12	24	19	25	23	16	27	24
0	10	3	11	9	12	24	19	24	25	15	27	25
0	8	4	10	8	10	26	19	24	24	15	27	25
0	8	6	11	8	10	26	18	24	25	15	26	25
0	7	7	10	11	10	25	19	23	25	16	29	24
0	6	7	9	9	11	25	19	23	24	16	28	24
0	6	6	9	9	10	25	20	23	25	17	28	23
0	6	7	10	9	10	25	20	22	27	16	26	24
1	5	6	10	9	11	23	20	21	27	16	27	24
1	5	7	12	7	13	22	20	22	25	16	26	25
1	5	8	15	6	14	20	20	22	24	17	27	23
2	6	8	15	5	15	20	19	22	24	16	26	23
3	6	11	15	6	14	21	19	22	23	16	24	21
3	5	11	17	7	15	20	20	22	26	17	24	23
2	6	12	16	7	17	22	20	21	26	17	21	23
1	6	13	13	7	18	22	21	21	26	17	22	24
3	6	13	12	7	18	23	22	21	25	17	22	24
3	6	13	8	7	18	22	23	22	24	18	22	24
3	7	12	9	7	20	21	23	22	25	21	22	27
4	9	12	9	8	20	21	22	23	25	21	22	27
4	12	11	9	8	20	24	22	22	23	21	23	28
5	12	12	8	7	21	22	22	24	21	22	22	28
6	11	10	8	7	22	22	21	24	20	22	22	27
6	11	7	7	8	21	21	22	22	20	23	25	
6	11	6	7	8	24	22	20	21	21	23	24	
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7	11	9	8	9	23	20	24	21	20	22	24	
8	11	9	8	9	23	20	24	22	21	22	24	
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11	7	13	14	12	21	17	24	22	20	23	24	
12	7	13	13	13	21	17	24	22	20	21	27	
14	7	15	13	13	20	16	25	21	21	21	27	
12	7	16	12	13	20	16	25	22	21	20	27	
13	4	15	12	12	21	17	25	22	22	20	27	
12	4	13	13	12	22	16	27	22	20	22	29	
13	4	13	12	11	22	18	24	22	19	25	29	

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EVENT 20
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NUMBER OF SENSORS WITH SIGNAL LESS THAN NOISE AT GIVEN FREQUENCY INDEX

	1	51	101	151	201	251	301	351	401	451	501	551	601	651	701
1	61	0	0	2	2	6	9	19	30	41	46	50	41	30	27
2	61	0	0	2	2	7	10	20	29	39	44	51	41	30	25
3	61	0	0	1	3	7	10	22	29	38	43	51	39	30	25
4	60	0	0	1	4	8	10	21	26	38	45	53	40	28	22
5	59	0	0	1	3	7	12	20	25	35	48	50	40	26	24
6	57	0	0	0	4	7	12	20	24	32	50	49	38	28	22
7	56	0	0	0	5	9	11	19	26	32	48	47	39	28	22
8	55	0	0	1	5	10	12	19	26	36	47	51	37	29	22
9	54	0	0	1	3	12	13	19	24	37	44	53	39	27	21
10	48	0	0	1	3	12	14	22	23	38	45	52	39	29	19
11	45	0	0	1	3	12	9	22	20	39	42	50	40	28	21
12	42	0	1	1	3	11	10	22	21	39	42	50	41	25	20
13	41	0	1	0	3	7	7	21	20	37	42	51	40	24	23
14	39	0	1	0	3	7	8	22	22	35	40	53	39	27	23
15	37	0	1	0	4	8	8	23	23	34	41	51	39	26	22
16	34	0	1	0	5	7	7	21	25	35	44	51	37	28	22
17	34	0	0	0	5	8	6	20	26	37	48	49	37	28	22
18	29	0	0	0	5	8	6	22	28	37	48	49	40	23	21
19	28	0	0	0	5	8	6	22	27	39	45	48	37	21	20
20	27	0	1	0	5	7	6	21	30	37	48	44	38	21	21
21	25	0	2	1	5	8	6	25	31	34	50	46	41	21	22
22	22	0	2	1	6	7	5	27	32	32	50	46	40	20	21
23	14	0	3	1	6	6	4	26	34	30	54	48	40	17	22
24	12	0	4	1	6	5	3	26	34	33	51	49	38	17	22
25	10	0	5	1	10	5	4	25	36	36	51	49	38	17	22
26	6	0	6	1	10	5	4	23	37	37	52	49	38	17	22
27	4	0	4	1	15	5	4	24	37	38	52	49	37	18	24
28	3	0	2	0	16	4	4	21	35	38	55	46	37	19	23
29	1	0	3	0	18	4	4	18	33	37	54	47	36	20	24
30	1	0	3	0	18	5	4	21	33	41	53	47	38	20	25
31	1	0	3	0	23	4	6	22	31	41	53	46	40	20	27
32	1	0	3	3	28	4	8	21	35	42	53	46	38	19	28
33	1	0	3	3	25	5	8	23	37	44	54	47	38	19	29
34	1	0	2	3	27	8	9	24	39	44	56	48	34	18	27
35	1	0	2	4	27	9	10	26	40	45	58	49	35	20	28
36	1	0	2	4	27	9	10	30	39	44	54	50	34	20	29
37	3	0	3	5	28	8	12	33	40	44	56	46	33	21	29
38	2	0	2	6	21	8	12	34	40	47	56	46	32	21	29
39	2	0	2	9	17	10	10	38	38	46	55	47	31	20	27
40	1	0	1	9	14	10	10	36	37	43	52	47	34	21	30
41	0	0	1	11	12	9	10	38	38	43	53	45	33	22	30
42	0	0	1	11	10	11	10	36	39	43	51	41	32	22	28
43	0	0	1	11	8	12	11	32	40	43	50	41	32	22	28
44	0	0	1	10	7	12	10	28	40	44	51	43	31	23	27
45	0	0	1	8	7	13	12	27	40	48	51	40	29	24	28
46	0	0	1	5	6	14	13	31	40	51	50	42	30	25	27
47	0	0	1	3	8	11	14	31	41	50	51	41	32	30	26
48	0	0	1	3	7	10	17	31	42	50	53	42	33	29	21
49	0	0	1	3	7	10	16	30	41	51	52	41	32	28	19
50	0	0	2	3	6	8	15	27	42	50	50	41	28	29	17

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IVEN FREQUENCY INDEX

01	451	501	551	601	651	701	751	801	851	901	951	1001
30	41	46	50	41	30	27	17	18	14	17	13	14
29	39	44	51	41	30	25	18	20	16	16	15	12
29	38	43	51	39	30	25	19	19	18	17	14	12
26	38	45	53	40	28	22	22	19	17	17	12	12
25	35	48	50	40	26	24	25	19	16	16	13	12
24	32	50	49	38	28	22	25	22	16	17	13	11
26	32	48	47	39	28	22	25	23	16	16	12	12
26	36	47	51	37	29	22	23	22	17	15	13	13
24	37	44	53	39	27	21	23	22	18	14	12	14
23	38	45	52	39	29	19	23	20	17	15	10	14
20	39	42	50	40	28	21	24	19	18	13	11	11
21	39	42	50	41	25	20	24	17	17	15	11	10
20	37	42	51	40	24	23	21	17	17	16	12	11
22	35	40	53	39	27	23	21	15	14	14	12	12
23	34	41	51	39	26	22	20	14	13	14	15	13
25	35	44	51	37	28	22	20	14	13	15	15	14
26	37	48	49	37	28	22	21	16	14	14	14	12
28	37	48	49	40	23	21	21	16	15	15	13	13
27	39	45	48	37	21	20	21	17	15	15	15	15
30	37	48	44	38	21	21	21	16	12	13	16	16
31	34	50	46	41	21	22	20	16	12	14	16	14
32	32	50	46	40	20	21	19	18	12	15	16	17
34	30	54	48	40	17	22	18	15	11	17	16	19
34	33	51	49	38	17	22	17	16	12	17	15	19
36	36	51	49	38	17	22	16	16	12	16	14	20
37	37	52	49	38	17	22	18	16	9	16	13	
37	38	52	49	37	18	24	21	16	8	14	13	
35	38	55	46	37	19	23	21	13	12	11	13	
33	37	54	47	36	20	24	24	15	12	10	12	
33	41	53	47	38	20	25	24	15	14	10	11	
31	41	53	46	40	20	27	25	16	14	12	11	
35	42	53	46	38	19	28	22	16	16	12	13	
37	44	54	47	38	19	29	19	13	17	12	13	
39	44	56	48	34	18	27	16	15	15	11	12	
40	45	58	49	35	20	28	16	17	14	13	12	
39	44	54	50	34	20	29	16	16	15	13	11	
40	44	56	46	33	21	29	15	16	16	12	12	
40	47	56	46	32	21	29	17	14	19	12	12	
38	46	55	47	31	20	27	17	14	19	12	14	
37	43	52	47	34	21	30	19	19	21	13	16	
38	43	53	45	33	22	30	19	19	20	14	16	
39	43	51	41	32	22	28	20	18	20	18	19	
40	43	50	41	32	22	28	21	16	22	19	18	
40	44	51	43	31	23	27	20	16	20	18	18	
40	48	51	40	29	24	28	18	17	19	17	17	
40	51	50	42	30	25	27	19	18	17	17	16	
41	50	51	41	32	30	26	17	17	18	17	15	
42	50	53	42	33	29	21	19	16	18	15	17	
41	51	52	41	32	28	19	19	14	18	15	16	
42	50	50	41	28	29	17	19	13	18	14	14	

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NUMBER OF SENSORS WITH SIGNAL LESS THAN NOISE AT GIVEN FREQUENCY INDEX

	1	51	101	151	201	251	301	351	401	451	501	551	601	651	701
1	30	0	0	0	0	0	0	0	0	0	0	0	2	2	1
2	30	0	0	0	0	0	0	0	0	0	0	0	2	3	1
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4	30	0	0	0	0	0	0	0	0	0	1	1	1	5	1
5	30	0	0	0	0	0	0	0	0	0	0	1	2	4	2
6	30	0	0	0	0	0	0	0	0	0	0	1	4	4	2
7	28	0	0	0	0	0	0	0	0	0	0	1	5	3	2
8	27	0	0	0	0	0	0	0	0	0	0	1	4	3	2
9	27	0	0	0	0	0	0	0	1	0	0	1	3	2	4
10	25	0	0	0	0	0	0	0	0	0	0	1	5	3	4
11	25	0	0	0	0	0	0	0	0	0	0	0	5	3	4
12	24	0	0	0	0	0	0	0	0	0	0	1	5	2	5
13	23	0	0	0	0	0	0	0	0	0	0	1	5	2	5
14	23	0	0	0	0	0	0	0	0	1	0	2	6	3	6
15	19	0	0	0	0	1	0	0	0	1	0	3	6	3	4
16	13	0	0	0	0	0	0	0	0	1	2	4	7	3	4
17	10	0	0	0	0	0	0	0	0	2	2	4	5	2	2
18	7	0	0	0	0	0	1	0	0	1	1	3	6	2	2
19	3	0	0	0	0	0	0	0	0	1	0	4	6	2	2
20	2	0	0	0	0	0	0	0	0	1	0	4	3	2	3
21	0	0	0	0	0	0	1	0	0	3	0	3	2	2	2
22	0	0	0	0	0	0	0	0	0	2	0	2	3	2	2
23	0	0	0	0	0	0	0	0	0	1	0	3	3	2	4
24	0	0	0	0	0	0	0	0	1	1	0	3	4	2	3
25	0	0	0	0	0	0	0	1	1	1	1	3	4	1	2
26	0	0	0	0	0	0	0	0	1	1	1	3	5	1	2
27	0	0	0	0	0	0	0	0	1	1	1	3	5	2	1
28	0	0	0	0	0	0	0	0	1	2	1	4	4	3	1
29	0	0	0	0	0	0	0	0	1	2	2	3	4	2	2
30	0	0	0	1	0	0	0	0	1	1	4	3	3	1	1
31	0	0	0	0	0	0	0	0	1	0	3	3	3	2	1
32	0	0	0	0	0	0	0	0	1	1	2	3	7	3	1
33	0	0	0	0	1	1	0	0	1	1	1	3	6	3	2
34	0	0	0	0	0	0	0	0	1	1	0	2	7	2	3
35	0	0	0	0	0	0	0	0	1	0	0	1	6	2	2
36	0	0	0	0	0	0	0	0	1	0	1	2	5	2	2
37	0	0	0	0	0	0	0	0	0	0	2	0	4	3	3
38	0	0	0	0	0	0	0	0	0	2	2	0	4	3	3
39	0	0	0	0	0	0	0	0	0	4	1	0	3	2	3
40	0	0	0	0	0	0	0	0	1	2	2	0	4	1	4
41	0	0	0	0	0	0	0	0	1	2	2	3	4	2	3
42	0	0	0	0	0	0	0	0	1	2	0	3	4	2	2
43	0	0	0	0	1	0	0	0	0	3	1	2	4	2	3
44	0	0	0	0	1	0	0	0	0	2	2	2	4	1	2
45	0	0	0	0	0	0	0	0	0	2	1	2	3	1	2
46	0	0	0	0	0	1	0	0	0	0	1	2	2	1	0
47	0	0	0	0	0	1	0	0	0	0	0	1	2	1	1
48	0	0	0	0	0	0	0	0	0	0	0	1	1	1	2
49	0	0	0	0	0	0	0	0	1	1	1	1	1	2	3
50	0	0	0	0	0	0	0	0	0	0	1	2	2	2	2

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IVEN FREQUENCY INDEX

01	451	501	551	601	651	701	751	801	851	901	951	1001
0	0	0	0	2	2	1	3	4	0	1	3	0
0	0	0	0	2	3	1	3	3	0	0	2	0
0	0	0	0	2	4	1	4	4	0	0	1	0
0	0	1	1	1	5	1	3	4	0	0	1	0
0	0	0	1	2	4	2	1	4	0	0	1	0
0	0	0	1	4	4	2	1	2	0	0	0	0
0	0	0	1	5	3	2	2	1	0	0	1	0
0	0	0	1	4	3	2	2	1	0	0	2	1
1	0	0	1	3	2	4	2	2	0	0	3	2
0	0	0	1	5	3	4	3	3	0	1	2	3
0	0	0	0	5	3	4	3	3	0	1	2	3
0	0	0	1	5	2	5	4	3	1	1	2	3
0	0	0	1	5	2	5	4	3	0	0	1	2
0	1	0	2	6	3	6	4	3	0	0	2	2
0	1	0	3	6	3	4	3	2	1	0	2	2
0	1	2	4	7	3	4	2	2	0	1	2	2
0	2	2	4	5	2	2	2	1	0	1	1	1
0	1	1	3	6	2	2	2	1	0	1	1	2
0	1	0	4	6	2	2	2	2	0	1	2	1
0	1	0	4	3	2	3	2	1	0	2	2	2
0	3	0	3	2	2	2	0	2	1	3	0	1
0	2	0	2	3	2	2	0	3	1	3	0	0
0	1	0	3	3	2	4	0	4	1	1	0	0
1	1	0	3	4	2	3	0	1	0	2	0	5
1	1	1	3	4	1	2	0	3	1	2	0	5
1	1	1	3	5	1	2	0	3	0	2	0	
1	1	1	3	5	2	1	0	2	0	1	0	
1	2	1	4	4	3	1	0	2	0	0	0	
1	2	2	3	4	2	2	0	4	0	0	0	
1	1	4	3	3	1	1	1	4	2	0	0	
1	0	3	3	3	2	1	1	4	2	0	1	
1	1	2	3	7	3	1	2	3	1	0	1	
1	1	1	3	6	3	2	2	2	2	1	1	
1	1	0	2	7	2	3	2	2	0	0	1	
1	0	0	1	6	2	2	2	3	0	1	0	
1	0	1	2	5	2	2	1	3	0	1	0	
0	0	2	0	4	3	3	3	2	0	2	0	
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0	4	1	0	3	2	3	3	1	1	1	0	
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1	2	2	3	4	2	3	2	2	1	2	1	
1	2	0	3	4	2	2	1	1	0	2	1	
0	3	1	2	4	2	3	1	1	0	3	2	
0	2	2	2	4	1	2	0	1	0	2	3	
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1	1	1	1	1	2	3	3	0	1	2	0	
0	0	1	2	2	2	2	3	0	2	3	0	

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NUMBER OF SENSORS WITH SIGNAL LESS THAN NOISE AT GIVEN FREQUENCY INDEX

	1	51	101	151	201	251	301	351	401	451	501	551	601	651	701
1	22	18	11	4	3	6	12	15	14	16	17	14	18	12	12
2	22	17	10	5	3	5	12	15	14	17	17	14	18	10	11
3	22	16	11	5	3	5	12	14	15	16	17	15	18	9	12
4	22	14	11	5	3	6	12	14	16	17	17	13	19	9	13
5	22	14	11	4	3	5	11	13	14	15	17	12	19	8	13
6	22	15	10	3	3	4	12	14	15	13	18	15	19	8	14
7	21	14	12	2	3	3	13	14	16	13	17	14	19	8	13
8	21	17	11	5	3	3	13	13	15	13	16	16	18	8	13
9	21	17	10	5	3	2	14	14	14	14	16	16	16	9	14
10	20	16	10	5	3	2	14	15	14	15	16	16	16	10	15
11	20	17	10	4	3	4	13	14	14	16	14	16	14	12	16
12	20	16	9	4	3	6	13	12	13	16	13	15	14	12	16
13	20	17	9	4	3	7	14	12	12	19	11	15	13	12	16
14	20	16	9	3	3	8	14	12	12	18	11	15	11	10	16
15	20	16	8	5	3	9	15	13	12	17	11	14	11	11	15
16	20	15	9	4	3	10	15	13	13	16	11	14	12	11	15
17	18	14	9	5	3	10	15	13	13	17	9	14	12	11	17
18	18	15	9	4	4	12	15	14	14	16	7	12	12	11	18
19	18	14	9	7	4	13	15	14	16	17	7	11	12	12	18
20	17	13	8	7	4	13	14	14	17	16	9	11	11	11	16
21	17	13	8	7	5	12	13	14	18	16	8	12	12	11	16
22	17	15	7	8	4	12	13	14	18	16	8	10	11	11	14
23	17	15	6	8	3	12	12	15	18	16	10	9	13	11	14
24	15	15	6	8	3	11	13	15	17	15	10	9	11	11	14
25	15	15	6	8	4	11	13	15	16	15	11	9	13	11	14
26	15	15	4	7	4	12	12	14	14	15	11	11	13	10	15
27	16	15	3	6	4	12	12	14	14	16	12	12	13	11	14
28	17	15	3	4	4	12	14	15	14	17	11	12	13	11	13
29	18	15	3	4	4	14	14	15	13	18	11	12	12	9	13
30	18	14	3	4	4	13	15	14	14	18	12	12	11	9	12
31	18	12	3	4	5	12	15	14	14	18	12	12	12	9	11
32	19	12	4	5	5	10	15	15	15	18	12	11	10	8	11
33	19	12	6	5	5	8	14	15	15	17	12	12	10	9	10
34	20	13	6	5	6	10	14	15	15	15	13	12	9	10	11
35	21	12	6	5	7	8	14	15	15	13	12	10	10	10	11
36	21	12	6	4	6	7	15	16	12	13	12	10	10	11	11
37	20	12	5	4	6	7	16	15	13	12	12	10	10	12	11
38	19	12	5	3	7	7	16	15	14	12	12	11	10	13	11
39	18	11	6	2	8	8	15	16	14	12	13	11	10	14	12
40	17	11	7	1	7	8	18	16	14	12	13	13	10	15	12
41	18	11	6	3	7	9	18	15	13	12	16	14	11	15	11
42	18	11	5	3	7	10	18	15	14	12	15	14	13	15	11
43	16	11	5	4	7	10	18	16	14	12	14	15	13	15	11
44	18	10	6	4	7	11	17	16	13	14	14	16	12	15	11
45	18	10	6	3	7	12	16	17	14	14	14	17	12	15	11
46	18	10	6	3	8	14	16	17	14	14	14	17	11	15	12
47	18	10	6	3	7	14	16	17	14	16	13	15	11	14	12
48	18	10	4	4	7	12	16	16	16	16	13	13	11	13	13
49	18	10	4	3	6	11	16	16	17	17	14	14	11	13	13
50	19	11	4	3	6	11	16	13	16	17	14	15	12	13	13

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GIVEN FREQUENCY INDEX

401	451	501	551	601	651	701	751	801	851	901	951	1001
14	16	17	14	18	12	12	12	13	12	10	14	14
14	17	17	14	18	10	11	13	13	13	10	14	14
15	16	17	15	18	9	12	12	12	15	10	15	14
16	17	17	13	19	9	13	12	12	14	11	15	13
14	15	17	12	19	8	13	11	11	14	13	15	14
15	13	18	15	19	8	14	11	12	14	13	15	14
16	13	17	14	19	8	13	11	13	14	12	15	12
15	13	16	16	18	8	13	11	13	13	12	16	12
14	14	16	16	16	9	14	11	12	14	12	18	12
14	15	16	16	16	10	15	12	12	16	12	18	13
14	16	14	16	14	12	16	12	12	14	12	18	13
13	16	13	15	14	12	16	13	11	12	12	16	13
12	19	11	15	13	12	16	14	12	11	12	16	13
12	18	11	15	11	10	16	15	12	11	12	16	13
12	17	11	14	11	11	15	16	12	10	12	16	14
13	16	11	14	12	11	15	18	12	11	13	16	15
13	17	9	14	12	11	17	18	12	11	13	15	15
14	16	7	12	12	11	18	17	12	12	12	16	15
16	17	7	11	12	12	18	16	13	12	13	15	17
17	16	9	11	11	11	16	16	12	13	13	15	16
18	16	8	12	12	11	16	16	12	14	13	13	16
18	16	8	10	11	11	14	15	12	15	14	13	14
18	16	10	9	13	11	14	16	13	16	15	14	14
17	15	10	9	11	11	14	16	13	15	16	14	14
16	15	11	9	13	11	14	16	13	13	16	14	14
14	15	11	11	13	10	15	17	13	12	16	13	
14	16	12	12	13	11	14	17	12	14	16	14	
14	17	11	12	13	11	13	17	13	14	16	12	
13	18	11	12	12	9	13	17	12	14	16	12	
14	18	12	12	11	9	12	17	12	15	14	14	
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15	18	12	11	10	8	11	17	13	14	13	15	
15	17	12	12	10	9	10	19	12	14	13	16	
15	15	13	12	9	10	11	19	12	13	12	17	
15	13	12	10	10	10	11	18	13	13	12	17	
12	13	12	10	10	11	11	17	12	13	11	17	
13	12	12	10	10	12	11	17	12	12	10	16	
14	12	12	11	10	13	11	16	11	13	11	17	
14	12	13	11	10	14	12	16	11	11	12	16	
14	12	13	13	10	15	12	15	10	11	12	14	
13	12	16	14	11	15	11	15	10	12	12	14	
14	12	15	14	13	15	11	14	10	13	12	15	
14	12	14	15	13	15	11	14	11	13	12	15	
13	14	14	16	12	15	11	13	10	13	11	15	
14	14	14	17	12	15	11	14	10	11	13	15	
14	14	14	17	11	15	12	15	10	11	13	15	
14	16	13	15	11	14	12	14	10	11	12	15	
16	16	13	13	11	13	13	13	11	12	12	14	
17	17	14	14	11	13	13	13	13	11	12	13	
16	17	14	15	12	13	13	12	13	10	13	14	

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A= 0.0 ON CHANNEL 113

A= 3.14 ON CHANNEL 114

NUMBER OF SENSORS WITH SIGNAL LESS THAN NOISE AT GIVEN FREQUENCY INDEX

	1	51	101	151	201	251	301	351	401	451	501	551	601	651	701
1	33	25	1	5	1	0	3	8	4	10	4	9	16	13	11
2	33	28	1	3	1	0	2	7	3	11	6	9	16	13	12
3	33	25	1	3	1	0	2	7	4	10	6	9	15	13	12
4	32	23	1	3	1	0	3	4	2	11	7	6	15	12	12
5	32	23	1	4	2	0	4	3	2	8	7	6	15	12	11
6	32	22	0	4	4	0	6	2	3	6	7	7	17	12	13
7	32	23	0	5	4	0	6	1	2	5	8	7	17	11	12
8	31	25	0	5	4	0	6	2	2	6	7	6	16	12	13
9	32	24	0	5	4	1	4	1	3	5	6	7	16	12	15
10	32	22	0	5	2	1	4	1	2	5	5	7	15	11	16
11	30	21	0	4	3	1	3	0	2	6	6	7	15	12	15
12	30	20	0	2	4	1	5	0	1	6	6	7	14	13	16
13	31	20	0	2	4	1	5	1	1	4	8	8	15	10	16
14	31	19	0	2	3	1	6	1	1	3	8	8	15	13	17
15	29	19	0	3	2	1	5	1	1	3	6	7	15	13	19
16	28	19	0	3	2	1	5	2	1	4	6	9	19	12	18
17	28	19	0	3	2	1	6	1	2	5	4	9	21	14	17
18	30	18	0	4	2	1	6	1	2	4	5	9	18	12	17
19	29	16	0	7	1	1	5	2	2	4	5	7	18	12	17
20	33	15	0	8	1	1	4	2	1	4	6	8	19	12	18
21	33	10	0	6	2	1	5	2	1	6	7	9	19	12	17
22	36	9	0	8	1	1	4	5	1	6	7	9	17	13	16
23	36	9	0	8	1	1	3	4	1	7	7	10	16	13	16
24	35	8	0	7	0	2	3	4	2	4	7	8	15	14	13
25	33	9	0	6	0	2	3	5	4	4	9	6	16	13	10
26	31	7	0	4	0	2	3	3	5	5	9	6	16	14	11
27	31	9	0	4	0	2	3	3	6	5	8	6	14	15	12
28	33	7	1	4	0	2	3	3	5	6	7	5	15	15	11
29	32	6	2	2	0	1	4	3	4	5	7	5	15	14	11
30	35	8	3	2	0	1	5	3	5	3	7	5	15	14	11
31	34	7	3	3	1	1	6	4	4	2	7	5	13	12	10
32	35	7	3	3	3	2	6	3	6	2	7	5	11	12	11
33	35	5	4	3	3	1	5	5	6	1	9	6	11	13	12
34	33	5	3	3	4	1	2	6	6	2	8	7	9	12	12
35	34	5	3	4	4	1	2	5	8	3	10	8	8	12	13
36	36	4	3	4	3	2	2	6	7	3	9	9	8	14	13
37	35	4	3	4	2	3	3	5	8	3	9	9	9	12	13
38	35	4	4	3	2	3	2	5	9	4	9	9	9	13	13
39	33	3	4	3	2	4	3	4	9	4	11	10	11	12	14
40	33	4	4	3	2	3	1	4	6	3	10	9	10	12	14
41	31	4	4	4	2	2	2	3	6	3	11	11	10	11	15
42	31	3	5	2	2	2	1	4	5	5	14	10	11	11	14
43	27	3	5	2	1	3	3	5	5	4	14	10	11	11	16
44	26	1	5	2	1	3	5	5	6	4	11	11	10	11	16
45	29	1	6	0	1	3	6	3	7	5	11	12	8	12	16
46	28	1	5	0	1	3	7	4	6	5	11	11	8	14	16
47	25	1	5	0	1	4	6	3	6	5	9	11	9	14	17
48	22	0	4	0	0	2	6	4	6	4	8	13	12	14	17
49	25	0	4	1	0	3	7	3	7	6	10	13	13	12	16
50	25	1	5	1	0	3	7	4	7	5	9	13	12	13	16

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GIVEN FREQUENCY INDEX

401	451	501	551	601	651	701	751	801	851	901	951	1001
4	10	4	9	16	13	11	19	16	10	13	12	16
3	11	6	9	16	13	12	16	16	9	12	12	16
4	10	6	9	15	13	12	15	16	10	12	12	15
2	11	7	6	15	12	12	15	15	11	14	13	15
2	8	7	6	15	12	11	16	18	13	14	13	16
3	6	7	7	17	12	13	16	18	13	12	14	12
2	5	8	7	17	11	12	15	19	15	14	12	12
2	6	7	6	16	12	13	17	17	16	15	12	14
3	5	6	7	16	12	15	16	16	18	19	12	12
2	5	5	7	15	11	16	15	16	17	16	14	12
2	6	6	7	15	12	15	15	15	18	15	15	11
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1	3	6	7	15	13	19	18	15	13	15	17	14
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2	5	4	9	21	14	17	20	16	11	17	15	14
2	4	5	9	18	12	17	17	15	11	16	13	15
2	4	5	7	18	12	17	18	16	10	16	14	15
1	4	6	8	19	12	18	17	16	11	15	14	17
1	6	7	9	19	12	17	16	17	11	14	13	19
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2	4	7	8	15	14	13	15	15	11	12	13	20
4	4	9	6	16	13	10	16	14	10	12	15	23
5	5	9	6	16	14	11	17	15	13	11	16	
6	5	8	6	14	15	12	17	15	13	9	16	
5	6	7	5	15	15	11	17	15	13	9	15	
4	5	7	5	15	14	11	16	15	11	10	13	
5	3	7	5	15	14	11	15	13	11	10	12	
4	2	7	5	13	12	10	13	13	10	9	12	
6	2	7	5	11	12	11	15	13	10	9	12	
6	1	9	6	11	13	12	15	11	9	10	12	
6	2	8	7	9	12	12	14	13	9	9	14	
8	3	10	8	8	12	13	16	12	11	9	14	
7	3	9	9	8	14	13	16	11	13	10	14	
8	3	9	9	9	12	13	17	9	11	12	15	
9	4	9	9	9	13	13	18	8	9	13	17	
9	4	11	10	11	12	14	19	9	11	14	16	
6	3	10	9	10	12	14	18	10	12	15	14	
6	3	11	11	10	11	15	19	8	13	15	15	
5	5	14	10	11	11	14	19	7	14	16	17	
5	4	14	10	11	11	16	19	8	15	15	18	
6	4	11	11	10	11	16	16	8	12	16	18	
7	5	11	12	8	12	16	16	8	11	16	18	
6	5	11	11	8	14	16	15	10	12	15	17	
6	5	9	11	9	14	17	16	13	11	15	17	
6	4	8	13	12	14	17	16	13	11	17	18	
7	6	10	13	13	12	16	16	11	12	12	18	
7	5	9	13	12	13	16	15	11	12	13	17	

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A= 0.0 ON CHANNEL 132

NUMBER OF SENSORS WITH SIGNAL LESS THAN NOISE AT GIVEN FREQUENCY INDEX

	1	51	101	151	201	251	301	351	401	451	501	551	601	651	701
1	49	11	0	1	5	10	17	10	51	34	23	40	38	38	34
2	49	9	0	0	3	9	15	10	51	32	21	41	36	39	36
3	51	9	0	0	3	10	15	9	53	31	20	42	38	41	35
4	49	8	0	0	3	11	15	11	53	29	19	43	40	41	31
5	49	5	0	0	2	12	16	14	50	29	19	45	41	40	34
6	48	4	0	0	2	11	15	15	49	29	22	45	40	38	36
7	52	3	0	0	3	13	17	15	49	33	26	41	40	38	40
8	52	1	0	0	3	17	17	15	47	34	28	41	37	37	41
9	52	1	0	1	3	16	19	14	45	34	29	43	37	35	39
10	53	1	0	1	3	17	19	16	47	35	28	43	37	35	39
11	53	1	0	2	3	19	22	17	44	30	31	41	36	35	41
12	55	1	0	3	2	19	22	18	42	30	30	42	36	35	42
13	56	1	0	4	3	18	18	17	44	29	32	44	38	36	40
14	56	1	0	4	4	15	18	18	47	27	34	44	37	36	38
15	55	1	0	4	4	14	13	20	45	25	35	40	34	36	37
16	54	1	0	4	4	9	15	23	40	26	36	40	35	37	37
17	54	2	0	4	4	9	15	24	37	24	37	39	36	39	40
18	52	2	0	4	5	10	16	24	33	23	36	37	36	38	41
19	52	2	0	4	4	9	16	24	35	23	36	36	35	38	42
20	52	2	0	4	4	9	17	27	37	24	36	38	38	36	43
21	51	2	0	5	4	9	19	27	36	24	40	37	37	36	44
22	51	2	1	4	3	10	18	29	38	22	40	36	37	38	42
23	52	2	1	4	2	11	19	30	36	21	38	35	39	37	42
24	53	1	1	5	0	12	21	30	35	20	38	34	38	38	43
25	53	0	1	5	1	12	20	30	37	20	37	33	42	39	46
26	52	0	1	5	1	14	18	32	39	19	37	31	43	41	43
27	55	0	1	7	1	13	17	32	42	20	36	31	46	40	46
28	56	0	1	7	1	14	17	31	39	23	35	33	48	38	46
29	57	0	1	5	1	16	13	31	37	23	35	32	51	36	45
30	56	0	2	3	1	17	13	33	36	21	34	34	50	37	46
31	55	0	2	4	0	18	12	32	34	23	33	32	46	40	43
32	54	0	1	4	0	18	12	32	30	29	34	36	46	42	41
33	53	0	1	4	0	21	11	30	30	29	31	40	45	43	39
34	49	0	1	4	0	24	10	29	28	27	31	43	41	40	35
35	48	0	1	4	1	28	11	28	26	29	26	44	42	43	35
36	43	0	1	4	2	32	12	26	28	29	28	43	40	42	33
37	36	0	1	4	2	28	11	26	30	30	29	45	41	43	33
38	34	0	1	4	2	27	12	27	31	30	30	44	39	41	39
39	29	0	1	4	3	20	13	26	29	31	30	45	40	41	37
40	25	0	1	4	4	23	13	25	31	32	32	47	38	35	36
41	24	0	1	4	5	23	12	27	33	30	31	46	37	35	36
42	19	0	1	4	7	21	13	31	33	31	31	47	37	37	36
43	16	0	1	4	7	22	13	33	27	31	31	49	36	39	33
44	16	0	1	5	8	21	14	34	27	30	32	48	38	38	34
45	15	0	1	5	8	19	13	36	29	31	35	46	35	37	36
46	14	1	1	5	9	16	12	39	31	33	31	46	37	33	35
47	15	1	1	5	13	18	11	42	30	29	31	43	39	33	34
48	15	0	1	5	12	18	11	44	31	29	33	39	38	33	30
49	15	0	1	5	11	19	12	46	33	26	33	37	39	34	27
50	14	0	1	5	11	17	10	50	33	25	38	37	39	35	30

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GIVEN FREQUENCY INDEX

401	451	501	551	601	651	701	751	801	851	901	951	1001
51	34	23	40	38	38	34	33	30	22	22	20	15
51	32	21	41	36	39	36	32	28	20	21	20	14
53	31	20	42	38	41	35	31	27	18	21	22	13
53	29	19	43	40	41	31	32	28	18	20	24	13
50	29	19	45	41	40	34	31	29	17	20	23	14
49	29	22	45	40	38	36	33	31	17	22	24	18
49	33	26	41	40	38	40	34	33	18	22	21	17
47	34	28	41	37	37	41	34	32	18	23	22	19
45	34	29	43	37	35	39	35	31	16	25	23	21
47	35	28	43	37	35	39	34	31	17	25	28	19
44	30	31	41	36	35	41	35	31	18	28	28	16
42	30	30	42	36	35	42	37	30	18	29	26	14
44	29	32	44	38	36	40	36	30	18	28	25	16
47	27	34	44	37	36	38	38	31	17	24	25	16
45	25	35	40	34	36	37	39	27	16	25	25	16
40	26	36	40	35	37	37	42	26	17	21	25	16
37	24	37	39	36	39	40	45	27	21	18	23	19
33	23	36	37	36	38	41	45	28	24	21	21	18
35	23	36	36	35	38	42	46	28	23	21	21	19
37	24	36	38	38	36	43	44	29	22	21	20	19
36	24	40	37	37	36	44	44	30	25	20	21	21
38	22	40	36	37	38	42	44	29	27	20	21	23
36	21	38	35	39	37	42	43	27	27	20	21	25
35	20	38	34	38	38	43	40	30	25	22	19	27
37	20	37	33	42	39	46	37	29	24	20	20	27
39	19	37	31	43	41	43	40	29	24	20	20	
42	20	36	31	46	40	46	37	32	28	20	20	
39	23	35	33	48	38	46	38	32	30	22	23	
37	23	35	32	51	36	45	37	32	27	20	23	
36	21	34	34	50	37	46	36	34	27	22	19	
34	23	33	32	46	40	43	36	35	27	23	18	
30	29	34	36	46	42	41	38	36	26	24	16	
30	29	31	40	45	43	39	36	35	23	21	14	
28	27	31	43	41	40	35	35	32	25	22	15	
26	29	26	44	42	43	35	30	32	25	22	16	
28	29	28	43	40	42	33	29	35	26	19	15	
30	30	29	45	41	43	33	27	38	21	21	13	
31	30	30	44	39	41	39	25	34	22	20	14	
29	31	30	45	40	41	37	28	31	25	22	15	
31	32	32	47	38	35	36	28	29	26	20	14	
33	30	31	46	37	35	36	26	28	26	21	15	
33	31	31	47	37	37	36	26	25	23	21	16	
27	31	31	49	36	39	33	29	27	24	24	16	
27	30	32	48	38	38	34	31	27	26	24	18	
29	31	35	46	35	37	36	32	27	26	21	21	
31	33	31	46	37	33	35	30	28	23	22	19	
30	29	31	43	39	33	34	32	26	23	18	17	
31	29	33	39	38	33	30	30	23	23	17	16	
33	26	33	37	39	34	27	32	23	25	18	16	
33	25	38	37	39	35	30	31	21	25	18	15	

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NUMBER OF SENSORS WITH SIGNAL LESS THAN NOISE AT GIVEN FREQUENCY INDEX

	1	51	101	151	201	251	301	351	401	451	501	551	601	651	701
1	44	27	1	0	0	0	0	2	1	1	32	13	7	18	14
2	44	26	1	0	0	0	0	5	1	1	31	13	6	17	13
3	44	25	1	0	0	0	0	5	1	1	29	13	6	17	14
4	45	29	2	0	0	0	0	4	2	2	28	14	6	18	13
5	47	27	2	0	0	0	0	4	1	2	27	17	8	20	14
6	46	26	2	0	0	0	0	4	2	1	26	17	8	22	18
7	47	26	2	0	0	1	0	6	2	1	21	17	8	25	19
8	46	26	2	0	0	0	0	5	2	1	21	15	10	24	19
9	46	23	2	1	1	0	0	3	1	1	15	16	11	23	20
10	47	22	2	0	1	0	0	4	1	1	14	14	11	22	21
11	47	20	2	0	1	0	0	3	1	1	13	14	11	21	20
12	46	16	5	0	1	0	0	3	1	1	14	15	11	22	19
13	46	16	5	0	0	0	0	3	2	1	11	15	13	18	20
14	45	17	7	0	0	0	0	3	1	1	13	14	13	18	22
15	47	17	7	0	1	0	0	3	1	2	13	14	13	16	22
16	47	16	8	0	1	0	1	4	2	2	11	15	11	14	22
17	47	15	9	0	1	0	1	3	2	2	13	13	10	16	22
18	45	12	10	0	1	0	1	5	2	3	13	13	10	14	20
19	45	10	10	0	1	0	1	6	2	2	13	13	11	16	21
20	47	10	13	0	1	0	1	6	1	3	16	16	13	18	21
21	45	10	21	0	2	1	0	5	2	4	13	15	14	17	21
22	43	9	31	0	2	0	0	5	3	4	15	12	14	15	23
23	42	7	38	0	2	0	0	3	2	7	14	11	14	11	23
24	42	5	47	0	2	1	0	1	2	6	15	9	15	12	23
25	45	5	43	0	2	1	0	2	2	7	15	10	15	16	20
26	47	7	32	0	2	1	1	2	1	7	16	9	12	16	21
27	49	7	25	1	2	0	1	1	2	7	14	8	12	17	21
28	48	6	17	2	2	0	1	1	1	7	13	9	12	19	22
29	47	4	10	1	1	0	0	0	2	10	13	9	11	19	22
30	46	3	8	1	0	1	0	0	3	10	12	10	12	19	20
31	45	2	5	1	0	2	0	1	2	9	14	12	13	21	18
32	45	2	2	1	0	0	0	1	1	11	15	10	14	24	18
33	43	1	2	0	0	0	0	1	2	11	15	12	11	22	16
34	42	0	2	0	0	0	0	2	3	12	15	10	13	24	18
35	44	0	1	0	1	0	0	1	1	11	15	9	11	23	17
36	39	0	2	0	0	0	0	1	1	15	14	10	12	24	19
37	40	1	2	0	0	0	0	0	2	18	13	9	12	22	15
38	38	2	2	0	0	0	1	0	3	19	11	9	11	22	16
39	38	2	1	0	0	0	1	1	4	21	10	9	14	22	16
40	37	2	1	0	0	0	0	1	3	22	9	6	15	22	15
41	36	2	1	0	0	0	0	1	3	24	10	7	16	24	16
42	34	2	0	0	0	0	0	1	3	27	12	7	17	21	16
43	34	1	0	0	0	0	0	1	2	26	12	7	17	22	15
44	34	2	0	0	0	0	1	1	2	27	12	6	16	22	16
45	34	2	0	0	0	0	1	1	3	25	13	7	15	19	18
46	33	2	0	0	0	0	2	1	3	25	13	10	17	20	19
47	33	1	0	0	0	0	2	1	2	25	14	9	16	19	18
48	30	1	0	0	0	0	2	1	2	25	13	9	17	17	18
49	29	1	0	0	0	0	1	1	1	29	14	9	16	15	19
50	28	1	0	0	0	0	2	1	1	31	12	7	18	14	18

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GIVEN FREQUENCY INDEX

401	451	501	551	601	651	701	751	801	851	901	951	1001
1	1	32	13	7	18	14	19	13	12	13	12	13
1	1	31	13	6	17	13	17	13	12	13	13	12
1	1	29	13	6	17	14	15	12	12	13	12	15
2	2	28	14	6	18	13	17	13	12	11	11	14
1	2	27	17	8	20	14	17	13	13	13	12	15
2	1	26	17	8	22	18	18	14	13	12	11	15
2	1	21	17	8	25	19	18	14	16	11	10	14
2	1	21	15	10	24	19	18	15	16	13	8	15
1	1	15	16	11	23	20	18	13	15	14	8	16
1	1	14	14	11	22	21	17	11	14	14	7	16
1	1	13	14	11	21	20	18	10	16	14	6	16
1	1	14	15	11	22	19	19	9	17	14	8	18
2	1	11	15	13	18	20	19	9	16	14	8	17
1	1	13	14	13	18	22	20	10	15	14	7	17
1	2	13	14	13	16	22	20	10	13	11	8	18
2	2	11	15	11	14	22	20	11	13	11	8	19
2	2	13	13	10	16	22	18	11	12	11	9	18
2	3	13	13	10	14	20	17	11	11	13	10	18
2	2	13	13	11	16	21	17	12	11	14	9	19
1	3	16	16	13	18	21	17	11	11	13	9	19
2	4	13	15	14	17	21	16	11	11	13	10	19
3	4	15	12	14	15	23	16	13	10	12	11	18
2	7	14	11	14	11	23	17	14	10	13	12	19
2	6	15	9	15	12	23	18	15	12	16	11	19
2	7	15	10	15	16	20	18	12	15	14	12	19
1	7	16	9	12	16	21	16	12	15	17	13	
2	7	14	8	12	17	21	16	14	13	16	12	
1	7	13	9	12	19	22	16	13	14	17	13	
2	10	13	9	11	19	22	18	10	14	15	14	
3	10	12	10	12	19	20	18	8	13	18	14	
2	9	14	12	13	21	18	18	7	15	15	13	
1	11	15	10	14	24	18	18	6	14	17	15	
2	11	15	12	11	22	16	17	5	12	13	14	
3	12	15	10	13	24	18	15	7	12	12	14	
1	11	15	9	11	23	17	14	9	15	10	14	
1	15	14	10	12	24	19	15	11	15	9	14	
2	18	13	9	12	22	15	17	11	14	8	13	
3	19	11	9	11	22	16	18	11	16	7	12	
4	21	10	9	14	22	16	15	11	17	7	13	
3	22	9	6	15	22	15	15	11	18	6	14	
3	24	10	7	16	24	16	13	12	17	7	14	
3	27	12	7	17	21	16	11	11	17	9	15	
2	26	12	7	17	22	15	11	14	17	10	17	
2	27	12	6	16	22	16	11	9	17	11	13	
3	25	13	7	15	19	18	10	9	15	9	14	
3	25	13	10	17	20	19	10	12	13	10	15	
2	25	14	9	16	19	18	10	12	12	10	17	
2	25	13	9	17	17	18	12	12	13	10	16	
1	29	14	9	16	15	19	12	14	12	12	16	
1	31	12	7	18	14	18	13	13	12	12	15	

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UMBER OF SENSORS WITH SIGNAL LESS THAN NOISE AT GIVEN FREQUENCY INDEX

	1	51	101	151	201	251	301	351	401	451	501	551	601	651	701	7
1	34	0	4	4	12	21	1	17	12	16	12	32	26	21	24	
2	34	0	3	6	4	23	0	16	10	18	11	33	26	20	22	
3	34	0	3	8	2	14	0	13	11	19	12	32	26	20	22	
4	34	0	4	9	1	10	0	13	12	21	16	30	27	21	21	
5	33	0	4	13	1	9	0	13	12	20	17	27	28	21	23	
6	32	0	3	17	1	7	0	11	12	21	19	30	28	22	22	
7	32	0	3	23	0	5	0	11	11	22	21	30	28	21	24	
8	35	0	4	28	0	6	0	10	10	18	20	28	25	22	22	
9	34	0	5	33	0	5	0	8	9	18	21	28	26	22	20	
0	34	0	6	34	1	5	1	7	8	18	19	28	27	23	20	
1	36	0	7	21	3	5	1	7	8	18	22	29	29	24	21	
2	36	0	8	9	4	4	1	7	8	17	24	28	29	25	18	
3	39	0	13	7	4	5	0	6	11	17	22	26	27	24	16	
4	40	1	24	6	4	5	0	7	13	17	23	26	27	21	16	
5	42	2	32	4	4	4	0	6	19	17	25	29	25	21	19	
6	44	2	23	2	4	4	0	6	24	18	27	29	24	21	18	
7	43	2	11	2	4	4	1	7	27	19	28	27	24	23	18	
8	39	2	5	2	4	3	1	7	28	19	27	30	24	25	18	
9	40	2	3	2	4	2	1	8	32	19	27	29	21	28	21	
20	38	3	0	2	5	0	1	8	34	20	28	29	20	26	21	
21	37	7	0	2	3	0	1	8	39	21	28	28	23	27	22	
22	34	11	0	1	3	0	1	12	38	21	27	27	24	27	23	
23	35	14	0	0	3	0	1	13	33	19	25	30	25	26	24	
24	34	14	0	0	3	0	2	14	30	19	25	32	24	26	24	
25	32	13	0	0	1	0	2	16	24	17	25	32	26	26	22	
26	29	10	1	0	1	0	2	18	18	19	25	32	27	25	23	
27	27	10	1	0	1	0	1	19	18	19	24	31	28	23	22	
28	26	9	1	1	0	0	1	21	14	18	26	31	27	23	18	
29	25	9	1	1	0	0	1	20	13	19	26	32	31	24	21	
30	23	10	1	1	0	0	1	21	11	21	26	33	31	22	23	
31	23	11	1	1	0	0	1	23	12	21	24	32	30	22	23	
32	24	14	1	1	1	0	1	23	10	23	24	31	31	17	23	
33	24	15	1	1	1	0	1	21	12	19	28	32	30	17	21	
34	24	14	1	1	1	0	1	17	12	20	25	31	31	20	21	
35	25	15	1	1	2	0	1	16	13	20	23	30	29	22	20	
36	25	23	1	1	2	0	3	16	15	18	20	31	28	22	21	
37	25	27	1	1	2	0	4	16	16	17	23	29	26	21	19	
38	18	35	1	2	3	0	4	15	16	17	23	28	22	20	18	
39	15	34	2	2	3	0	5	12	16	16	23	27	21	19	18	
40	14	30	2	2	4	0	4	13	16	17	21	25	20	17	18	
41	12	24	2	2	4	0	5	14	21	17	29	24	19	19	19	
42	9	18	2	2	4	0	7	15	21	17	28	21	19	21	19	
43	7	16	2	2	4	0	8	14	19	16	28	22	18	23	18	
44	5	13	3	3	5	0	9	14	19	19	28	24	19	24	18	
45	2	13	3	5	7	1	11	15	19	20	32	22	20	23	19	
46	1	11	3	7	7	2	14	13	21	20	31	24	20	24	19	
47	1	10	2	10	6	2	23	14	20	17	30	26	20	23	21	
48	1	6	2	13	11	2	24	13	20	15	31	27	20	26	18	
49	0	6	2	17	13	1	23	13	16	12	33	26	21	25	17	
50	0	4	4	14	13	1	22	13	17	12	32	27	22	26	16	

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GIVEN FREQUENCY INDEX

401	451	501	551	601	651	701	751	801	851	901	951	1001
12	16	12	32	26	21	24	16	12	23	13	20	16
10	18	11	33	26	20	22	19	14	23	14	19	17
11	19	12	32	26	20	22	19	15	22	15	19	17
12	21	16	30	27	21	21	21	16	21	14	17	18
12	20	17	27	28	21	23	20	16	21	14	17	17
12	21	19	30	28	22	22	23	15	18	13	19	19
11	22	21	30	28	21	24	23	16	17	13	18	19
10	18	20	28	25	22	22	22	18	17	12	18	19
9	18	21	28	26	22	20	22	17	15	13	16	19
8	18	19	28	27	23	20	22	17	14	12	15	18
8	18	22	29	29	24	21	24	17	17	13	16	18
8	17	24	28	29	25	18	25	17	14	12	16	18
11	17	22	26	27	24	16	28	18	13	12	18	17
13	17	23	26	27	21	16	29	19	14	15	19	19
19	17	25	29	25	21	19	28	17	14	14	21	19
24	18	27	29	24	21	18	30	15	14	14	21	16
27	19	28	27	24	23	18	27	15	14	17	20	14
28	19	27	30	24	25	18	28	15	17	16	19	19
32	19	27	29	21	28	21	27	19	17	16	19	21
34	20	28	29	20	26	21	26	18	15	14	19	20
39	21	28	28	23	27	22	25	21	15	11	17	23
38	21	27	27	24	27	23	22	20	12	9	18	21
33	19	25	30	25	26	24	24	19	11	10	15	21
30	19	25	32	24	26	24	23	19	8	11	15	20
24	17	25	32	26	26	22	21	16	9	7	14	20
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11	21	26	33	31	22	23	20	19	13	13	16	
12	21	24	32	30	22	23	21	19	10	13	14	
10	23	24	31	31	17	23	15	21	10	9	15	
12	19	28	32	30	17	21	16	20	8	9	17	
12	20	25	31	31	20	21	15	21	9	8	16	
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16	16	23	27	21	19	18	14	23	9	16	14	
15	17	21	25	20	17	18	14	22	8	16	14	
21	17	29	24	19	19	19	16	22	10	18	14	
21	17	28	21	19	21	19	18	22	11	21	14	
19	16	28	22	18	23	18	19	20	13	20	15	
19	19	28	24	19	24	18	17	20	14	26	17	
19	20	32	22	20	23	19	18	23	16	24	17	
21	20	31	24	20	24	19	18	22	14	24	18	
20	17	30	26	20	23	21	18	21	12	23	16	
20	15	31	27	20	26	18	17	20	12	22	16	
16	12	33	26	21	25	17	15	20	11	20	17	
17	12	32	27	22	26	16	13	22	12	20	16	

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NUMBER OF SENSORS WITH SIGNAL LESS THAN NOISE AT GIVEN FREQUENCY INDEX

	1	51	101	151	201	251	301	351	401	451	501	551	601	651	701
1	32	34	6	2	2	0	0	3	12	26	33	28	38	40	37
2	32	35	6	2	2	0	0	4	15	29	32	26	37	37	38
3	31	33	6	2	3	0	1	5	21	29	34	26	39	37	38
4	31	32	6	2	3	2	1	6	20	28	33	28	39	40	40
5	33	33	8	2	3	2	0	7	19	28	31	29	39	38	37
6	34	31	8	2	3	3	0	8	19	28	31	28	41	41	37
7	34	30	8	2	3	3	0	8	18	28	29	29	42	42	38
8	34	27	7	3	5	3	0	7	17	27	29	30	42	44	36
9	34	28	9	3	7	1	0	8	18	27	30	32	40	42	36
10	36	28	9	3	10	2	1	7	18	26	31	29	40	41	38
11	35	26	10	3	9	2	1	7	19	24	31	29	42	36	37
12	35	28	9	3	8	3	2	8	19	23	31	26	44	39	36
13	36	27	9	3	7	3	3	7	21	24	32	28	42	40	37
14	36	25	9	5	7	3	3	7	25	26	31	29	38	39	36
15	37	22	7	6	7	3	3	7	26	26	31	26	38	41	31
16	39	19	8	7	6	3	3	6	25	27	30	28	39	42	31
17	39	18	10	8	5	3	3	6	26	27	30	26	39	45	30
18	39	13	8	8	4	3	3	6	26	28	31	27	40	43	32
19	40	10	9	8	4	2	3	8	26	32	31	28	40	42	31
20	41	11	10	8	4	2	5	10	27	36	31	29	40	41	31
21	43	8	10	8	2	2	5	10	26	36	31	30	39	44	32
22	43	9	10	11	1	2	5	10	25	35	32	30	40	44	31
23	44	8	10	12	1	2	5	10	23	36	30	31	39	42	30
24	46	8	11	14	1	2	5	11	20	36	30	34	41	43	30
25	48	8	12	14	1	2	5	13	21	34	32	33	42	39	29
26	48	7	10	13	1	2	5	13	22	32	32	35	45	35	31
27	46	7	12	16	1	2	5	16	22	34	32	37	43	35	31
28	46	6	14	17	1	2	4	15	22	36	31	39	40	36	32
29	43	8	14	20	1	2	5	14	26	35	32	38	40	34	33
30	43	9	14	20	0	3	7	15	25	34	31	36	41	33	32
31	42	8	12	21	0	3	7	16	26	33	32	37	39	34	34
32	43	9	11	23	0	3	6	16	21	33	31	36	41	35	32
33	42	9	10	22	0	3	5	17	21	32	32	35	43	36	34
34	41	9	9	22	0	4	3	17	21	30	32	31	42	39	35
35	41	10	8	20	0	5	2	16	20	29	31	30	42	41	34
36	41	10	7	16	0	6	2	15	19	29	31	28	41	42	34
37	41	10	7	13	0	6	2	16	17	29	31	28	42	42	35
38	42	9	8	10	0	6	2	15	17	24	32	27	42	39	34
39	42	9	7	7	0	6	1	15	16	25	30	28	41	38	33
40	44	9	7	7	0	7	1	14	17	25	29	29	44	40	33
41	45	8	7	5	1	6	1	12	20	24	27	31	43	39	32
42	44	6	8	3	1	6	1	11	21	26	27	32	44	37	31
43	42	5	7	3	1	5	1	11	22	27	26	34	42	36	33
44	40	4	6	3	0	5	1	11	25	30	25	33	40	38	36
45	40	4	7	2	0	3	2	10	25	30	27	35	40	42	38
46	41	5	7	2	0	0	2	9	24	28	27	36	39	41	39
47	40	4	5	2	0	0	2	9	24	29	28	37	39	42	37
48	38	5	4	3	0	0	2	10	24	27	28	36	40	42	34
49	37	5	2	3	0	0	2	11	25	30	28	38	40	41	34
50	36	5	2	3	0	0	3	11	25	31	27	37	42	41	37

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401	451	501	551	601	651	701	751	801	851	901	951	1001
12	26	33	28	38	40	37	38	31	33	20	26	23
15	29	32	26	37	37	38	37	31	34	19	29	26
21	29	34	26	39	37	38	36	32	33	20	27	24
20	28	33	28	39	40	40	36	36	34	22	27	24
19	28	31	29	39	38	37	35	34	33	23	28	25
19	28	31	28	41	41	37	36	34	33	22	27	27
18	28	29	29	42	42	38	35	36	32	22	27	25
17	27	29	30	42	44	36	35	36	31	23	27	25
18	27	30	32	40	42	36	37	37	30	23	24	23
18	26	31	29	40	41	38	37	33	29	22	24	24
19	24	31	29	42	36	37	35	34	28	21	24	25
19	23	31	26	44	39	36	36	34	29	25	24	25
21	24	32	28	42	40	37	36	32	30	29	23	25
25	26	31	29	38	39	36	37	35	29	28	25	26
26	26	31	26	38	41	31	37	36	27	30	27	28
25	27	30	28	39	42	31	38	33	31	31	26	27
26	27	30	26	39	45	30	39	32	32	33	26	26
26	28	31	27	40	43	32	35	32	35	34	26	24
26	32	31	28	40	42	31	32	29	36	37	26	26
27	36	31	29	40	41	31	33	29	37	38	27	24
26	36	31	30	39	44	32	31	29	33	36	28	22
25	35	32	30	40	44	31	30	29	31	36	27	20
23	36	30	31	39	42	30	31	29	27	35	29	24
20	36	30	34	41	43	30	32	30	27	36	28	26
21	34	32	33	42	39	29	31	30	26	34	28	26
22	32	32	35	45	35	31	31	33	26	32	30	
22	34	32	37	43	35	31	31	35	23	32	29	
22	36	31	39	40	36	32	30	34	24	31	29	
26	35	32	38	40	34	33	32	32	23	28	29	
25	34	31	36	41	33	32	32	29	23	28	28	
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21	33	31	36	41	35	32	34	29	22	28	30	
21	32	32	35	43	36	34	35	30	23	28	31	
21	30	32	31	42	39	35	32	31	21	28	31	
20	29	31	30	42	41	34	30	35	18	26	31	
19	29	31	28	41	42	34	28	36	20	24	29	
17	29	31	28	42	42	35	27	36	20	25	27	
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16	25	30	28	41	38	33	29	35	24	22	26	
17	25	29	29	44	40	33	28	34	25	22	24	
20	24	27	31	43	39	32	27	34	23	23	24	
21	26	27	32	44	37	31	27	33	24	23	24	
22	27	26	34	42	36	33	27	33	25	23	24	
25	30	25	33	40	38	36	28	35	26	23	25	
25	30	27	35	40	42	38	30	34	23	25	25	
24	28	27	36	39	41	39	30	35	25	24	25	
24	29	28	37	39	42	37	28	34	23	24	24	
24	27	28	36	40	42	34	30	33	22	24	26	
25	30	28	38	40	41	34	30	30	21	24	27	
25	31	27	37	42	41	37	30	32	21	26	26	

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NUMBER OF SENSORS WITH SIGNAL LESS THAN NOISE AT GIVEN FREQUENCY INDEX

	1	51	101	151	201	251	301	351	401	451	501	551	601	651
1	21	23	6	0	0	2	20	19	20	23	20	17	20	19
2	20	23	6	0	0	2	19	17	20	24	20	19	20	18
3	19	22	5	0	0	2	21	15	20	24	18	19	20	18
4	18	22	4	0	0	2	20	15	19	25	17	19	17	18
5	18	20	4	0	0	4	20	15	20	25	19	18	15	18
6	17	19	3	1	0	5	20	14	20	26	19	19	17	17
7	16	21	3	1	0	5	20	15	20	26	19	18	17	16
8	15	20	3	1	0	5	21	16	21	25	20	18	16	13
9	15	20	3	1	0	4	21	15	20	24	20	18	15	13
10	15	20	3	1	0	3	20	16	22	24	19	20	15	13
11	15	19	4	1	0	2	20	16	22	24	19	19	16	14
12	15	18	3	1	0	3	19	16	21	23	21	20	17	15
13	16	15	3	1	0	3	19	18	22	23	23	20	17	16
14	16	15	2	2	0	3	18	19	21	23	23	19	17	17
15	17	15	2	2	0	6	17	20	19	21	24	20	17	17
16	16	15	2	3	0	7	19	20	19	22	24	20	17	17
17	15	15	2	3	0	7	19	20	18	21	22	20	17	15
18	15	14	2	2	0	7	19	20	18	18	21	21	18	15
19	14	13	3	2	0	7	19	19	16	18	21	20	17	13
20	15	12	3	2	0	7	17	17	16	17	21	24	16	13
21	15	12	3	2	0	8	17	16	16	19	21	24	16	11
22	14	11	3	2	1	7	18	16	17	18	22	24	17	12
23	15	9	4	2	1	9	19	16	17	17	21	24	17	12
24	15	9	4	2	1	12	20	16	17	18	20	26	17	13
25	18	10	4	2	1	12	23	16	17	17	18	26	16	12
26	19	9	3	2	1	13	24	17	15	18	18	26	18	12
27	19	10	2	1	1	12	24	16	15	17	17	26	18	11
28	19	10	2	1	1	13	25	14	12	20	16	23	18	12
29	19	10	3	1	1	13	24	14	12	20	15	23	18	12
30	17	11	3	1	2	13	26	14	12	21	16	23	16	13
31	17	11	3	1	2	13	26	14	14	21	17	23	17	13
32	16	9	3	2	4	12	25	16	13	21	17	23	18	13
33	16	9	2	2	5	13	22	16	13	21	17	23	19	13
34	17	9	2	2	6	13	21	16	16	20	18	22	19	13
35	18	8	2	2	6	13	19	15	19	21	16	21	20	13
36	21	8	1	2	6	15	18	14	19	22	16	21	20	13
37	21	9	1	2	5	15	19	16	20	21	17	22	21	14
38	20	9	1	2	4	15	18	18	21	22	16	23	18	14
39	20	8	1	2	5	15	20	18	19	20	18	20	20	14
40	20	8	1	2	5	16	17	19	20	21	18	22	19	17
41	20	8	1	2	5	16	17	18	21	21	19	22	19	15
42	20	7	1	1	4	15	16	20	22	20	19	21	20	15
43	19	7	1	0	3	16	17	18	22	20	17	22	19	15
44	19	6	2	0	3	13	17	16	22	21	16	24	19	15
45	19	3	2	0	3	14	19	16	22	21	17	22	19	16
46	21	4	2	0	4	15	18	16	19	21	16	23	21	17
47	23	4	0	0	3	16	18	17	22	21	15	21	21	15
48	21	4	0	0	3	17	18	17	22	20	15	20	20	16
49	21	6	0	0	3	17	18	19	23	20	15	20	20	18
50	23	6	0	0	3	19	19	20	23	20	15	20	20	17

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GIVEN FREQUENCY INDEX

401	451	501	551	601	651	701	751	801	851	901	951	1001
20	23	20	17	20	19	16	17	17	16	21	12	25
20	24	20	19	20	18	17	18	16	16	19	13	27
20	24	18	19	20	18	16	17	16	17	18	15	24
19	25	17	19	17	18	16	18	16	17	19	16	24
20	25	19	18	15	18	15	16	17	17	20	16	19
20	26	19	19	17	17	15	15	16	18	19	15	19
20	26	19	18	17	16	14	17	14	18	21	16	20
21	25	20	18	16	13	14	16	14	17	21	15	21
20	24	20	18	15	13	14	16	13	17	20	15	20
22	24	19	20	15	13	14	17	13	15	18	13	20
22	24	19	19	16	14	13	19	13	15	18	14	19
21	23	21	20	17	15	12	19	14	15	19	13	16
22	23	23	20	17	16	12	20	15	15	19	14	15
21	23	23	19	17	17	13	21	14	15	19	14	14
19	21	24	20	17	17	13	23	15	15	18	16	15
19	22	24	20	17	17	12	20	15	16	18	16	14
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21	22	16	23	18	14	17	21	17	17	20	18	
19	20	18	20	20	14	17	20	17	18	18	15	
20	21	18	22	19	17	16	19	16	18	17	17	
21	21	19	22	19	15	17	19	15	16	17	17	
22	20	19	21	20	15	17	15	15	15	15	16	
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22	20	15	20	20	16	15	16	14	18	13	24	
23	20	15	20	20	18	18	16	16	21	14	25	
23	20	15	20	20	17	17	17	16	21	13	26	

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NUMBER OF SENSORS WITH SIGNAL LESS THAN NOISE AT GIVEN FREQUENCY INDEX

	1	51	101	151	201	251	301	351	401	451	501	551	601	651	701
1	62	67	54	12	3	2	6	0	3	0	8	4	6	17	35
2	62	67	50	13	3	2	6	0	1	0	7	4	5	17	35
3	62	67	50	11	2	3	5	1	1	0	5	4	5	15	35
4	60	68	49	10	1	3	5	2	1	1	5	3	5	15	34
5	60	69	46	9	1	2	4	2	0	1	4	3	6	16	36
6	60	69	44	9	1	1	4	2	0	2	4	3	8	17	36
7	59	65	41	9	1	1	5	1	0	2	5	4	7	18	39
8	57	66	40	8	1	1	5	1	0	2	7	3	8	16	40
9	55	64	38	7	2	1	5	0	0	2	7	5	9	20	38
10	54	63	38	7	2	0	3	0	0	3	7	5	10	19	40
11	54	64	35	8	2	0	4	0	0	4	7	6	12	21	43
12	58	67	34	8	2	0	4	0	0	4	5	6	9	21	44
13	58	68	34	9	1	0	3	1	0	4	5	6	11	22	44
14	59	68	33	7	1	0	2	1	0	3	4	6	12	25	42
15	61	71	33	7	2	0	2	1	0	2	3	8	13	24	44
16	62	67	33	6	3	0	1	1	0	0	3	10	12	24	46
17	62	68	32	7	3	0	1	1	0	0	3	7	10	21	44
18	64	66	32	6	2	0	1	1	0	0	5	6	11	21	46
19	61	65	29	6	3	0	2	1	1	0	7	5	11	20	43
20	61	66	27	6	4	0	1	2	1	2	7	4	13	22	42
21	62	64	28	4	5	0	1	2	0	2	7	2	12	24	43
22	63	63	27	4	5	0	1	1	0	3	9	2	13	24	44
23	64	60	27	5	5	0	1	1	0	2	10	2	12	26	43
24	61	59	27	5	5	0	1	2	0	2	8	2	13	26	44
25	61	60	27	7	4	0	1	2	0	1	7	2	13	25	43
26	61	61	28	8	4	0	1	2	2	0	8	2	10	28	39
27	62	64	27	8	4	0	1	2	4	1	7	0	10	29	42
28	65	59	27	8	3	1	2	1	3	1	7	0	10	28	42
29	63	57	27	8	4	1	2	1	2	2	8	1	11	28	42
30	58	55	26	6	4	2	2	2	1	2	9	3	15	28	39
31	58	56	23	6	3	2	2	4	1	2	8	2	15	27	36
32	60	57	23	5	3	5	2	5	1	2	9	2	14	25	35
33	61	59	23	4	3	4	2	5	1	4	7	3	12	25	36
34	60	57	23	4	3	3	2	5	2	3	7	3	12	27	35
35	62	61	23	4	3	3	3	3	2	3	7	3	11	27	35
36	62	63	19	3	2	3	2	2	2	2	5	3	12	28	34
37	62	62	17	3	3	2	1	3	1	1	3	3	13	28	36
38	62	59	18	3	2	2	1	5	0	2	3	3	13	28	38
39	63	59	17	4	3	2	0	7	0	2	4	3	12	27	37
40	60	60	15	3	3	3	0	8	0	3	3	3	15	30	35
41	59	57	15	3	3	3	0	8	0	3	2	2	15	32	36
42	59	56	13	3	3	2	0	7	0	3	1	2	16	35	39
43	62	57	13	4	3	4	0	7	0	4	1	3	18	34	41
44	66	56	13	4	2	4	0	6	0	3	1	4	18	35	38
45	67	53	13	5	3	5	0	5	0	3	2	4	19	33	36
46	68	53	12	4	2	5	0	4	0	4	2	5	18	31	39
47	68	53	12	3	2	6	0	6	0	4	2	4	20	31	41
48	68	55	12	3	1	7	0	5	0	5	2	3	19	34	41
49	70	58	13	3	1	4	0	5	0	6	4	5	19	36	44
50	69	56	13	3	1	6	1	3	0	6	4	5	19	36	40

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GIVEN FREQUENCY INDEX

401	451	501	551	601	651	701	751	801	851	901	951	1001
3	0	8	4	6	17	35	41	52	46	47	55	47
1	0	7	4	5	17	35	41	48	46	46	58	50
1	0	5	4	5	15	35	43	47	49	46	58	48
1	1	5	3	5	15	34	41	52	49	49	57	44
0	1	4	3	6	16	36	39	52	48	48	58	45
0	2	4	3	8	17	36	38	52	46	47	59	46
0	2	5	4	7	18	39	39	53	44	51	58	47
0	2	7	3	8	16	40	39	54	47	48	57	48
0	2	7	5	9	20	38	37	54	49	50	58	50
0	3	7	5	10	19	40	36	52	50	47	55	48
0	4	7	6	12	21	43	38	50	53	45	56	52
0	4	5	6	9	21	44	38	54	52	44	54	53
0	4	5	6	11	22	44	38	53	49	45	53	52
0	3	4	6	12	25	42	40	50	49	42	53	52
0	2	3	8	13	24	44	41	48	48	46	53	52
0	0	3	10	12	24	46	39	47	47	45	54	51
0	0	3	7	10	21	44	39	52	51	46	53	52
0	0	5	6	11	21	46	37	52	52	46	52	52
1	0	7	5	11	20	43	37	52	50	50	48	53
1	2	7	4	13	22	42	38	54	49	52	50	55
0	2	7	2	12	24	43	38	53	48	53	50	57
0	3	9	2	13	24	44	38	53	46	54	49	57
0	2	10	2	12	26	43	38	53	45	54	48	56
0	2	8	2	13	26	44	42	51	46	55	46	58
0	1	7	2	13	25	43	39	53	46	56	48	58
2	0	8	2	10	28	39	39	53	49	55	48	
4	1	7	0	10	29	42	40	55	48	55	47	
3	1	7	0	10	28	42	44	55	45	54	44	
2	2	8	1	11	28	42	44	52	43	54	44	
1	2	9	3	15	28	39	44	58	42	55	44	
1	2	8	2	15	27	36	46	57	45	52	45	
1	2	9	2	14	26	35	47	53	45	53	44	
1	4	7	3	12	25	36	43	52	45	49	45	
2	3	7	3	12	27	35	45	53	43	48	44	
2	3	7	3	11	27	35	40	54	43	51	46	
2	2	5	3	12	28	34	42	51	46	50	47	
1	1	3	3	13	28	36	41	52	48	51	48	
0	2	3	3	13	28	38	40	55	50	51	46	
0	2	4	3	12	27	37	44	53	49	51	45	
0	3	3	3	15	30	35	43	55	48	53	47	
0	3	2	2	15	32	36	44	53	48	53	49	
0	3	1	2	16	35	39	44	53	48	54	49	
0	4	1	3	18	34	41	45	55	50	54	49	
0	3	1	4	18	35	38	47	55	50	54	48	
0	3	2	4	19	33	36	50	52	47	54	48	
0	4	2	5	18	31	39	51	51	46	54	46	
0	4	2	4	20	31	41	49	48	46	54	46	
0	5	2	3	19	34	41	50	45	45	55	47	
0	6	4	5	19	36	44	52	48	48	58	47	
0	6	4	5	19	36	40	52	47	48	52	47	

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NUMBER OF SENSORS WITH SIGNAL LESS THAN NOISE AT GIVEN FREQUENCY INDEX

	1	51	101	151	201	251	301	351	401	451	501	551	601	651	701
1	57	51	2	4	0	0	1	0	1	0	0	0	6	4	5
2	57	51	2	4	0	0	1	0	1	0	0	0	6	3	5
3	56	52	2	4	0	0	1	0	1	0	0	0	5	2	4
4	57	51	2	2	0	0	0	0	1	0	0	0	5	2	3
5	57	48	2	2	0	0	1	0	1	0	0	1	4	1	3
6	56	50	2	2	0	0	1	0	0	0	0	1	2	1	3
7	53	50	2	2	0	0	2	0	0	0	0	1	3	2	4
8	51	48	2	2	0	0	2	0	1	0	0	0	2	1	5
9	52	45	2	1	0	0	1	0	2	0	0	0	3	0	5
10	54	44	3	1	0	1	0	0	2	0	0	0	3	1	4
11	54	47	3	1	0	1	0	0	0	0	0	0	3	1	3
12	55	46	3	2	0	1	0	0	0	0	0	1	3	2	3
13	52	44	3	2	0	1	1	0	0	0	0	0	2	2	3
14	52	41	1	1	0	0	1	0	0	0	1	0	2	3	3
15	52	41	1	1	0	0	1	0	0	0	2	0	2	3	3
16	53	40	1	0	0	0	1	0	1	0	2	0	3	2	2
17	51	37	1	0	1	0	1	0	0	0	1	2	3	2	2
18	51	31	2	0	1	0	1	0	0	0	1	2	3	2	1
19	48	28	3	0	0	0	0	0	0	0	1	2	3	2	1
20	48	26	3	0	0	0	0	1	0	0	0	2	3	4	1
21	47	23	3	0	0	1	0	0	0	0	0	2	3	3	3
22	48	24	3	0	0	0	0	0	1	0	0	1	2	3	3
23	50	22	3	0	1	0	0	0	0	0	0	1	2	3	3
24	53	19	3	0	0	0	0	0	0	0	0	0	2	3	3
25	53	18	3	0	0	0	0	1	0	0	0	0	2	5	3
26	52	17	3	0	0	0	0	1	1	0	0	1	3	4	3
27	49	14	3	0	0	0	0	1	1	0	1	2	3	3	3
28	50	15	4	0	0	0	0	1	1	0	0	3	3	3	1
29	51	15	4	0	0	1	0	0	1	0	1	3	3	3	2
30	49	10	3	0	2	1	0	0	0	0	1	3	3	4	4
31	50	10	3	1	2	0	0	0	2	0	2	3	2	4	4
32	53	8	3	1	2	0	0	0	1	0	2	2	2	4	4
33	50	6	2	1	2	0	0	0	2	0	1	1	2	4	3
34	52	3	2	2	0	0	0	1	0	0	1	1	1	6	2
35	51	3	2	1	0	1	0	1	0	0	0	1	1	8	2
36	50	0	2	1	0	1	0	0	0	0	0	2	3	6	3
37	50	0	1	1	0	2	0	0	1	0	0	2	7	5	4
38	46	0	1	1	0	2	0	0	1	0	0	3	7	5	4
39	45	0	1	1	0	3	0	0	1	0	0	4	6	6	5
40	43	0	1	0	0	2	1	0	2	0	0	4	4	6	6
41	43	0	1	0	0	1	1	0	2	0	0	3	6	5	6
42	45	0	1	0	0	2	0	0	2	0	0	3	5	4	8
43	45	0	0	0	0	2	0	0	1	0	0	3	5	4	8
44	46	1	0	0	0	3	0	0	0	0	1	3	3	4	7
45	44	1	0	0	0	2	0	0	0	0	1	4	3	3	7
46	41	1	1	0	0	1	0	0	0	0	0	3	3	3	8
47	46	2	2	0	0	1	0	0	0	0	0	4	3	3	9
48	47	2	2	0	0	1	0	0	1	0	0	4	3	3	8
49	50	2	2	0	0	0	0	1	0	0	0	4	4	3	8
50	52	2	4	0	0	1	0	1	0	0	0	5	5	4	7

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01	451	501	551	601	651	701	751	801	851	901	951	1001
1	0	0	0	6	4	5	6	2	14	12	16	20
1	0	0	0	6	3	5	6	2	16	14	17	21
1	0	0	0	5	2	4	5	2	17	14	16	21
1	0	0	0	5	2	3	4	3	16	15	20	23
1	0	0	1	4	1	3	4	5	14	15	19	22
0	0	0	1	2	1	3	5	5	14	16	18	22
0	0	0	1	3	2	4	5	4	11	17	18	22
1	0	0	0	2	1	5	6	4	9	17	17	24
2	0	0	0	3	0	5	6	4	8	18	18	27
2	0	0	0	3	1	4	6	5	9	18	19	27
0	0	0	0	3	1	3	4	5	9	20	18	26
0	0	0	1	3	2	3	4	4	9	20	18	26
0	0	0	0	2	2	3	5	3	12	21	18	25
0	0	1	0	2	3	3	5	5	13	20	19	25
0	0	2	0	2	3	3	6	6	14	19	19	27
1	0	2	0	3	2	2	7	8	16	19	19	28
0	0	1	2	3	2	2	7	9	16	18	21	29
0	0	1	2	3	2	1	8	7	16	20	22	30
0	0	1	2	3	2	1	6	8	17	20	24	30
0	0	0	2	3	4	1	5	7	16	19	23	30
0	0	0	2	3	3	3	4	7	14	21	23	30
1	0	0	1	2	3	3	4	7	12	22	23	35
0	0	0	1	2	3	3	4	7	12	22	23	36
0	0	0	0	2	3	3	4	7	15	21	20	36
0	0	0	0	2	5	3	4	8	15	20	20	37
1	0	0	1	3	4	3	3	7	15	18	18	
1	0	1	2	3	3	3	3	6	14	19	18	
1	0	0	3	3	3	1	4	7	13	21	17	
1	0	1	3	3	3	2	6	7	13	21	17	
0	0	1	3	3	4	4	5	8	11	23	18	
2	0	2	3	2	4	4	6	9	11	22	19	
1	0	2	2	2	4	4	7	10	13	25	19	
2	0	1	1	2	4	3	7	10	13	23	17	
0	0	1	1	1	6	2	5	9	13	21	15	
0	0	0	1	1	8	2	5	7	15	20	15	
0	0	0	2	3	6	3	4	10	16	19	16	
1	0	0	2	7	5	4	3	12	11	18	17	
1	0	0	3	7	5	4	4	13	12	16	17	
1	0	0	4	6	6	5	4	12	13	17	15	
2	0	0	4	4	6	6	4	13	14	17	15	
2	0	0	3	6	5	6	4	13	14	16	14	
2	0	0	3	5	4	8	3	12	15	18	14	
1	0	0	3	5	4	8	3	12	15	18	15	
0	0	1	3	3	4	7	3	11	15	16	14	
0	0	1	4	3	3	7	4	12	14	16	15	
0	0	0	3	3	3	8	5	11	15	17	18	
0	0	0	4	3	3	9	5	11	14	15	19	
1	0	0	4	3	3	8	5	12	13	15	17	
0	0	0	4	4	3	8	4	13	13	15	17	
0	0	0	5	5	4	7	4	14	12	16	18	

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NUMBER OF SENSORS WITH SIGNAL LESS THAN NOISE AT GIVEN FREQUENCY INDEX

	1	51	101	151	201	251	301	351	401	451	501	551	601	651	701
1	5	1	0	0	0	1	0	1	4	3	4	1	0	4	1
2	5	0	0	1	0	2	0	1	4	3	4	1	0	4	1
3	5	0	0	0	1	2	0	1	4	3	3	1	0	4	1
4	5	0	0	0	1	2	0	1	4	3	3	1	1	3	1
5	5	0	0	0	1	3	0	1	4	4	3	1	1	2	1
6	5	0	0	0	1	3	0	1	3	5	4	1	2	2	1
7	5	0	0	0	1	3	0	1	3	5	3	2	2	3	1
8	6	0	0	0	1	3	0	1	3	5	3	2	2	3	1
9	6	0	0	0	1	3	0	1	3	4	3	2	2	3	1
10	6	0	0	0	1	3	0	1	3	4	2	2	2	3	0
11	6	0	0	1	1	3	0	1	2	4	2	2	3	3	0
12	6	0	0	1	1	3	0	1	2	4	2	2	3	3	0
13	7	0	0	1	1	2	0	1	3	4	1	1	3	3	0
14	7	0	0	0	1	2	0	1	3	3	1	0	3	3	0
15	7	0	0	0	1	3	0	0	3	3	1	0	3	3	1
16	7	0	0	0	1	3	0	0	3	3	1	0	4	3	1
17	7	0	0	0	0	3	0	0	3	3	1	0	5	4	1
18	7	0	0	0	0	2	0	0	3	3	2	0	6	3	1
19	7	0	0	0	0	1	0	0	3	3	2	0	6	3	1
20	7	0	0	0	0	1	0	0	3	3	2	0	5	3	1
21	7	0	0	0	0	1	0	1	3	2	2	0	5	3	2
22	7	0	0	0	0	1	0	1	2	2	1	0	5	3	2
23	7	0	0	1	0	1	0	1	2	3	1	0	4	2	2
24	6	0	0	1	0	1	0	1	2	3	2	0	3	2	2
25	5	0	0	1	0	1	0	1	2	3	2	0	2	2	2
26	5	0	0	0	1	2	0	1	3	3	2	0	2	2	2
27	5	0	0	0	1	2	0	1	3	3	2	0	2	2	2
28	5	0	0	0	1	2	0	1	3	3	2	0	2	2	2
29	5	0	0	0	1	2	0	1	4	3	3	0	2	2	2
30	5	0	0	0	3	1	0	1	4	2	3	0	2	2	2
31	6	0	0	0	3	1	0	1	4	2	3	0	2	2	2
32	6	0	0	0	3	1	0	0	4	1	4	0	1	2	2
33	7	0	0	0	3	1	0	0	4	1	4	0	1	2	2
34	6	0	0	0	3	1	0	0	4	2	3	0	1	2	3
35	6	0	0	0	3	1	0	0	5	2	2	0	1	2	3
36	5	0	0	0	3	2	0	1	5	2	3	0	1	2	3
37	4	0	0	0	3	3	0	1	5	3	3	0	1	1	3
38	4	0	0	0	3	3	0	1	5	3	3	0	1	1	3
39	4	0	0	0	2	3	0	1	5	3	2	0	1	1	3
40	4	0	0	0	2	3	0	1	5	4	2	0	1	1	2
41	3	0	0	0	2	3	0	1	6	4	3	0	1	1	2
42	1	0	0	0	2	3	0	2	6	3	3	0	1	1	2
43	1	0	0	0	1	3	0	2	6	3	2	0	3	1	2
44	1	0	0	0	1	3	0	2	5	3	3	0	3	1	2
45	1	0	0	0	1	3	0	2	4	2	2	0	3	1	1
46	1	0	0	0	0	2	0	4	4	2	2	0	3	1	1
47	1	0	0	0	0	1	0	4	4	2	1	0	3	1	1
48	1	0	0	0	0	1	0	4	4	2	1	0	3	1	1
49	1	0	0	0	0	0	1	4	3	3	1	0	5	1	1
50	1	0	0	0	1	0	1	4	3	3	1	0	4	1	1

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T GIVEN FREQUENCY INDEX

401	451	501	551	601	651	701	751	801	851	901	951	1001
4	3	4	1	0	4	1	1	4	3	1	2	1
4	3	4	1	0	4	1	2	4	3	1	2	1
4	3	3	1	0	4	1	2	4	2	1	2	1
4	3	3	1	1	3	1	2	4	2	1	2	1
4	4	3	1	1	2	1	2	4	2	1	2	1
3	5	4	1	2	2	1	2	4	1	1	2	1
3	5	3	2	2	3	1	2	4	1	1	2	0
3	5	3	2	2	3	1	1	3	1	1	2	0
3	4	3	2	2	3	1	1	3	1	2	2	0
3	4	2	2	2	3	0	1	3	1	1	2	1
2	4	2	2	3	3	0	1	3	1	1	1	1
2	4	2	2	3	3	0	1	3	1	1	1	2
3	4	1	1	3	3	0	1	3	1	0	1	2
3	3	1	0	3	3	0	2	3	1	0	2	3
3	3	1	0	3	3	1	2	3	1	0	2	2
3	3	1	0	4	3	1	2	3	1	0	2	3
3	3	1	0	5	4	1	2	3	1	0	2	3
3	3	2	0	6	3	1	2	3	1	0	2	3
3	3	2	0	6	3	1	2	3	1	0	1	2
3	3	2	0	5	3	1	2	3	1	0	1	2
3	2	2	0	5	3	2	2	2	2	1	1	2
2	2	1	0	5	3	2	2	2	2	1	1	2
2	3	1	0	4	2	2	2	2	2	1	1	2
2	3	2	0	3	2	2	2	2	2	1	1	2
2	3	2	0	2	2	2	2	2	2	1	1	2
3	3	2	0	2	2	2	2	2	2	1	1	
3	3	2	0	2	2	2	2	2	2	2	1	
3	3	2	0	2	2	2	2	2	2	2	2	
4	3	3	0	2	2	2	1	2	2	2	2	
4	2	3	0	2	2	2	1	2	2	2	2	
4	2	3	0	2	2	2	1	2	2	1	2	
4	1	4	0	1	2	2	1	2	2	1	2	
4	1	4	0	1	2	2	2	2	3	1	1	
4	2	3	0	1	2	3	2	2	3	1	1	
5	2	2	0	1	2	3	2	2	3	1	1	
5	2	3	0	1	2	3	2	2	3	1	1	
5	3	3	0	1	1	3	2	2	3	3	1	
5	3	3	0	1	1	3	2	2	3	2	1	
5	3	2	0	1	1	3	2	2	1	2	1	
5	4	2	0	1	1	2	2	2	1	2	1	
6	4	3	0	1	1	2	2	2	1	2	1	
6	3	3	0	1	1	2	2	2	1	2	1	
6	3	2	0	3	1	2	2	2	1	2	1	
5	3	3	0	3	1	2	2	2	0	2	2	
4	2	2	0	3	1	1	2	2	0	2	2	
4	2	2	0	3	1	1	2	2	0	2	1	
4	2	1	0	3	1	1	2	3	1	2	1	
4	2	1	0	3	1	1	3	3	1	2	1	
3	3	1	0	5	1	1	2	3	1	2	1	
3	3	1	0	4	1	1	2	3	1	2	1	

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A= 0.0 ON CHANNEL 130

A= 3.14 ON CHANNEL 132

NUMBER OF SENSORS WITH SIGNAL LESS THAN NOISE AT GIVEN FREQUENCY INDEX

	1	51	101	151	201	251	301	351	401	451	501	551	601	651	701
1	55	41	43	4	1	5	22	19	20	19	22	36	55	50	50
2	56	34	39	3	1	6	23	20	23	19	22	40	53	47	48
3	55	30	40	3	0	6	24	18	21	17	22	43	52	47	48
4	53	26	42	2	0	8	25	19	22	15	24	43	49	46	44
5	55	26	40	2	0	6	23	20	19	18	23	41	50	47	41
6	55	22	40	4	0	5	23	21	20	16	23	39	50	53	42
7	54	19	40	5	0	4	22	23	21	17	24	39	50	51	43
8	54	19	41	5	1	4	22	22	25	20	29	41	46	49	44
9	48	16	41	5	1	2	21	21	24	22	28	41	48	48	41
10	48	16	40	6	1	2	19	18	26	21	30	40	49	45	45
11	48	15	36	6	2	2	16	18	27	20	33	48	46	43	45
12	47	19	36	5	1	3	17	17	28	22	29	49	48	45	42
13	46	19	31	7	1	2	15	17	28	21	31	48	47	43	41
14	41	22	29	8	1	1	16	18	27	23	33	49	49	45	42
15	37	27	28	8	1	3	17	20	30	24	32	46	42	47	40
16	30	34	27	10	1	3	13	20	32	27	36	46	43	46	39
17	28	36	23	9	1	5	12	17	38	27	37	47	43	48	38
18	23	37	20	7	1	6	14	17	39	25	39	43	41	51	40
19	20	41	21	5	1	5	17	16	38	24	36	40	41	51	44
20	20	47	19	3	1	7	18	14	34	23	37	40	44	51	48
21	18	50	16	3	1	7	17	14	32	22	37	38	41	53	48
22	15	50	15	3	2	6	17	11	28	21	39	39	38	55	46
23	14	55	15	4	1	7	18	10	28	18	35	37	36	55	48
24	13	53	13	4	1	6	17	11	25	16	33	37	37	54	45
25	11	52	11	4	0	6	17	9	24	17	29	38	37	56	46
26	9	46	10	4	1	7	16	8	23	19	31	35	38	56	43
27	10	49	8	4	1	5	18	7	22	20	28	31	41	55	42
28	10	48	8	4	1	5	19	9	22	21	30	30	38	57	45
29	8	49	4	3	2	5	19	9	24	21	32	29	35	54	44
30	7	54	5	4	2	5	19	9	25	21	31	32	38	52	45
31	5	56	6	4	3	6	18	7	26	22	32	31	41	52	45
32	7	56	6	4	5	7	15	8	27	27	34	33	43	53	46
33	6	58	5	4	8	7	14	7	26	27	34	36	44	53	50
34	6	57	5	6	8	14	13	7	25	26	36	35	44	52	52
35	6	56	5	5	8	19	14	12	28	27	40	34	44	52	52
36	9	56	4	4	8	24	15	15	30	30	44	33	46	53	54
37	8	56	7	5	9	25	16	13	29	29	48	34	44	54	58
38	9	57	11	4	10	29	16	12	32	25	50	38	42	54	57
39	12	55	11	4	10	30	16	12	35	27	48	39	41	53	56
40	18	55	11	3	11	31	17	11	35	27	48	40	43	51	56
41	21	50	16	3	10	26	18	14	33	27	45	38	42	53	57
42	25	50	25	5	8	29	19	15	38	26	45	41	46	52	55
43	29	50	36	4	7	32	19	15	37	22	42	44	44	52	53
44	31	44	40	3	7	32	19	17	33	21	35	44	42	52	55
45	35	50	32	3	6	28	20	19	26	21	36	43	42	54	56
46	42	52	19	2	5	22	21	21	25	22	36	44	44	57	55
47	47	46	14	3	6	23	23	22	20	22	35	45	44	57	56
48	45	42	11	2	6	22	24	22	21	20	36	49	43	56	56
49	43	45	8	2	5	23	24	21	21	22	40	51	47	54	55
50	43	42	8	2	5	22	24	22	20	20	38	52	48	52	55

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GIVEN FREQUENCY INDEX

401	451	501	551	601	651	701	751	801	851	901	951	1001
20	19	22	36	55	50	50	56	46	52	44	43	43
23	19	22	40	53	47	48	55	46	48	46	42	40
21	17	22	43	52	47	48	57	45	51	48	43	39
22	15	24	43	49	46	44	56	43	52	49	45	40
19	18	23	41	50	47	41	51	44	53	49	46	43
20	16	23	39	50	53	42	51	43	51	47	43	43
21	17	24	39	50	51	43	53	47	49	49	39	42
25	20	29	41	46	49	44	57	48	52	48	38	42
24	22	28	41	48	48	41	58	49	53	47	37	44
26	21	30	40	49	45	45	56	48	52	51	34	40
27	20	33	48	46	43	45	55	50	46	49	36	41
28	22	29	49	48	45	42	55	50	48	49	37	41
28	21	31	48	47	43	41	53	48	46	48	37	40
27	23	33	49	49	45	42	53	48	46	45	35	42
30	24	32	46	42	47	40	54	48	45	44	30	35
32	27	36	46	43	46	39	51	47	45	42	33	36
38	27	37	47	43	48	38	47	45	46	44	35	38
39	25	39	43	41	51	40	48	45	45	43	36	39
38	24	36	40	41	51	44	44	44	44	43	37	41
34	23	37	40	44	51	48	41	45	43	44	39	41
32	22	37	38	41	53	48	48	44	50	40	37	43
28	21	39	39	38	55	46	46	44	48	38	42	43
28	18	35	37	36	55	48	46	45	50	38	43	46
25	16	33	37	37	54	45	48	46	49	36	42	48
24	17	29	38	37	56	46	49	43	50	35	42	49
23	19	31	35	38	56	43	47	42	52	35	42	
22	20	28	31	41	55	42	46	41	50	37	43	
22	21	30	30	38	57	45	47	41	51	40	42	
24	21	32	29	35	54	44	45	42	51	37	43	
25	21	31	32	38	52	45	45	45	53	39	44	
26	22	32	31	41	52	45	46	43	58	39	38	
27	27	34	33	43	53	46	47	44	56	40	42	
26	27	34	36	44	53	50	48	45	57	42	40	
25	26	36	35	44	52	52	49	43	55	43	38	
28	27	40	34	44	52	52	49	44	54	39	35	
30	30	44	33	46	53	54	48	41	54	39	38	
29	29	48	34	44	54	58	45	39	54	38	38	
32	25	50	38	42	54	57	44	42	53	38	40	
35	27	48	39	41	53	56	43	42	52	37	39	
35	27	48	40	43	51	56	44	42	53	41	37	
33	27	45	38	42	53	57	43	42	52	39	37	
38	26	45	41	46	52	55	39	40	53	37	36	
37	22	42	44	44	52	53	39	40	53	38	36	
33	21	35	44	42	52	55	38	40	52	38	40	
26	21	36	43	42	54	56	39	43	54	40	40	
25	22	36	44	44	57	55	42	45	55	40	38	
20	22	35	45	44	57	56	44	45	57	40	39	
21	20	36	49	43	56	56	43	46	54	39	40	
21	22	40	51	47	54	55	44	44	51	38	40	
20	20	38	52	48	52	55	46	50	47	37	41	

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NUMBER OF SENSORS WITH SIGNAL LESS THAN NOISE AT GIVEN FREQUENCY INDEX

	1	51	101	151	201	251	301	351	401	451	501	551	601	651	701
1	36	39	20	17	2	2	9	7	6	9	9	6	4	12	13
2	36	38	21	16	2	2	9	7	6	9	8	6	4	11	14
3	35	36	22	14	3	2	8	8	6	9	10	5	5	10	12
4	36	36	20	13	3	2	7	10	4	9	9	5	6	10	13
5	37	35	20	13	3	2	8	9	4	10	9	5	7	10	13
6	36	33	18	12	3	2	7	7	4	9	8	5	6	9	14
7	39	35	19	9	5	2	7	6	4	7	10	8	7	10	12
8	39	33	16	10	5	2	7	8	4	6	11	8	7	10	14
9	38	31	11	10	4	2	8	7	5	7	10	7	6	10	15
10	39	32	11	10	4	2	7	6	6	6	10	7	8	10	17
11	39	35	10	9	4	2	6	5	6	5	10	7	7	10	19
12	37	35	10	9	3	2	7	5	5	6	10	7	8	9	[illegible]
13	37	36	9	10	3	2	6	4	6	6	9	5	8	9	21
14	36	36	11	10	3	2	6	3	6	8	10	5	8	8	21
15	37	37	11	9	2	2	5	3	6	9	9	6	8	7	21
16	35	37	11	9	2	1	4	3	8	10	10	6	8	7	19
17	35	36	10	8	2	1	4	3	8	11	10	7	9	8	19
18	35	38	9	7	4	1	4	2	8	12	10	8	8	9	18
19	35	36	9	7	4	0	4	1	8	12	10	8	8	10	18
20	35	35	8	6	4	1	3	2	7	11	10	8	7	11	17
21	34	35	11	5	3	1	4	3	7	14	9	8	5	12	15
22	34	34	12	5	3	2	4	2	5	13	9	8	6	12	16
23	34	33	13	6	3	1	6	3	6	13	10	9	7	11	17
24	35	32	13	6	3	1	5	3	8	12	11	9	8	10	15
25	34	31	13	5	3	1	3	5	9	13	11	7	8	10	15
26	34	30	13	4	3	1	3	4	8	14	12	7	6	9	15
27	36	27	13	4	3	1	3	4	8	14	12	8	6	10	15
28	36	24	13	4	3	1	3	5	8	13	12	7	7	11	15
29	40	25	10	3	3	2	2	6	7	12	12	7	7	11	17
30	38	23	9	3	3	2	1	6	7	12	12	7	8	11	17
31	40	24	7	3	2	2	1	7	6	10	12	7	10	12	18
32	41	23	10	3	2	1	1	7	4	11	11	7	11	12	17
33	39	23	11	3	3	2	1	8	5	9	11	7	10	11	18
34	38	23	12	3	3	3	2	7	5	9	9	8	10	11	17
35	38	22	13	3	2	3	2	6	6	9	5	10	10	11	17
36	36	22	13	3	2	3	3	5	6	9	5	10	9	11	16
37	39	23	12	3	2	4	5	6	7	8	4	10	9	10	15
38	39	23	13	1	2	3	5	7	7	8	5	9	9	11	15
39	40	25	11	2	2	5	5	7	6	7	5	8	8	11	16
40	39	23	11	2	2	6	5	6	6	4	5	8	9	10	16
41	40	24	10	2	1	6	5	6	7	3	5	6	9	9	15
42	39	25	15	2	1	6	5	5	8	4	4	5	12	10	13
43	37	23	17	2	2	7	5	5	9	5	5	6	13	10	14
44	38	21	17	2	1	6	6	6	9	5	4	5	13	10	14
45	37	22	19	3	2	6	6	7	9	6	3	4	14	11	16
46	38	23	20	3	2	7	3	8	9	6	3	5	14	11	17
47	36	21	17	4	2	7	3	8	8	7	4	5	13	10	18
48	39	21	21	4	3	7	4	8	9	9	5	5	13	10	17
49	37	19	20	4	3	7	5	8	9	9	5	5	12	10	16
50	37	19	18	2	2	9	5	7	10	9	6	5	13	12	14

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IVEN FREQUENCY INDEX

01	451	501	551	601	651	701	751	801	851	901	951	1001
6	9	9	6	4	12	13	15	20	31	23	23	24
6	9	8	6	4	11	14	15	20	33	22	23	22
6	9	10	5	5	10	12	19	18	33	22	22	23
4	9	9	5	6	10	13	17	19	32	23	22	22
4	10	9	5	7	10	13	19	22	31	25	21	21
4	9	8	5	6	9	14	18	24	31	27	21	21
4	7	10	8	7	10	12	21	24	30	24	20	20
4	6	11	8	7	10	14	20	26	28	24	21	20
5	7	10	7	6	10	16	19	24	29	23	22	19
6	6	10	7	8	10	17	19	25	27	25	24	22
6	5	10	7	7	10	19	20	26	26	25	24	23
5	6	10	7	8	9	20	21	26	24	25	25	23
6	6	9	5	8	9	21	22	27	22	24	26	22
6	8	10	5	8	8	21	22	27	22	22	27	21
6	9	9	6	8	7	21	22	27	21	21	27	20
8	10	10	6	8	7	19	22	25	24	24	27	18
8	11	10	7	9	8	19	24	25	27	24	27	22
8	12	10	8	8	9	18	24	24	27	23	28	22
8	12	10	8	8	10	18	25	25	28	25	26	24
7	11	10	8	7	11	17	25	24	26	28	26	25
7	14	9	8	5	12	15	28	25	22	28	26	23
5	13	9	8	6	12	16	29	23	25	26	26	26
6	13	10	9	7	11	17	30	24	24	25	25	25
8	12	11	9	8	10	15	29	23	25	22	25	24
9	13	11	7	8	10	15	29	23	26	22	29	25
8	14	12	7	6	9	15	27	24	29	20	27	
8	14	12	8	6	10	15	25	22	28	21	29	
8	13	12	7	7	11	15	25	21	25	22	30	
7	12	12	7	7	11	17	24	21	25	20	30	
7	12	12	7	8	11	17	23	20	27	22	31	
6	10	12	7	10	12	18	24	20	28	25	29	
4	11	11	7	11	12	17	24	20	28	25	27	
5	9	11	7	10	11	18	24	20	27	26	28	
5	9	9	8	10	11	17	26	24	26	29	27	
6	9	5	10	10	11	17	22	25	26	25	26	
6	9	5	10	9	11	16	21	25	26	28	26	
7	8	4	10	9	10	15	20	26	26	28	26	
7	8	5	9	9	11	15	20	26	27	26	27	
6	7	5	8	8	11	16	20	23	28	28	26	
6	4	5	8	9	10	16	21	30	26	29	25	
7	3	5	6	9	9	15	21	32	25	25	26	
8	4	4	5	12	10	13	21	31	24	24	25	
9	5	5	6	13	10	14	22	32	21	24	28	
9	5	4	5	13	10	14	22	34	22	24	26	
9	6	3	4	14	11	16	21	35	23	22	24	
9	6	3	5	14	11	17	21	35	25	24	25	
8	7	4	5	13	10	18	22	35	24	25	26	
9	9	5	5	13	10	17	23	33	24	23	25	
9	9	5	5	12	10	16	21	29	23	23	25	
10	9	6	5	13	12	14	20	31	21	23	26	

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NUMBER OF SENSORS WITH SIGNAL LESS THAN NOISE AT GIVEN FREQUENCY INDEX

	1	51	101	151	201	251	301	351	401	451	501	551	601	651	701
1	26	20	1	0	0	4	6	12	14	21	24	32	29	28	23
2	26	20	1	0	0	4	6	10	12	21	23	33	31	28	23
3	26	19	1	0	2	2	6	9	13	21	25	31	30	29	21
4	27	19	2	0	2	2	6	9	13	19	25	29	30	29	21
5	28	20	2	0	2	2	6	8	15	17	24	28	31	31	22
6	25	21	2	0	2	2	8	8	16	18	24	30	31	30	20
7	25	20	3	0	2	3	8	9	17	18	25	29	28	31	21
8	25	20	4	0	2	3	9	8	16	20	27	28	27	31	22
9	26	18	4	0	2	4	9	8	18	22	28	31	28	32	21
10	26	18	4	0	2	5	11	9	16	22	30	31	29	32	19
11	28	17	4	0	2	5	12	10	15	21	29	31	29	32	19
12	29	14	4	0	2	5	15	10	16	20	27	30	28	30	20
13	29	15	4	0	5	5	16	11	16	19	26	33	26	29	19
14	28	15	3	0	5	6	16	12	15	18	27	32	26	29	21
15	27	15	3	0	5	6	15	13	18	17	28	32	28	29	20
16	27	15	3	0	6	7	15	13	20	17	28	29	27	30	21
17	25	15	3	0	6	8	15	14	20	15	29	30	26	32	22
18	25	16	2	0	5	6	16	16	21	14	28	30	24	31	22
19	23	15	2	1	4	6	20	16	20	16	26	29	25	31	22
20	20	15	2	1	4	5	21	17	20	16	28	30	25	29	23
21	20	15	2	1	3	4	20	15	19	16	28	31	24	29	24
22	21	17	2	1	4	4	21	13	19	16	27	31	27	28	25
23	21	18	1	1	6	3	19	12	19	19	28	32	26	28	24
24	22	17	1	1	8	3	18	13	21	18	26	34	25	27	25
25	24	17	0	1	8	4	15	13	21	20	27	34	26	27	24
26	25	15	0	1	8	5	13	12	20	20	30	34	26	28	25
27	25	14	0	1	9	6	14	11	20	19	30	36	27	27	25
28	24	13	0	1	11	6	17	10	18	21	32	38	29	28	26
29	24	11	0	0	13	6	15	12	18	22	30	38	29	28	26
30	24	10	0	0	14	5	15	12	19	22	29	38	31	27	23
31	24	9	0	0	15	5	14	13	18	24	28	39	28	26	23
32	25	9	0	0	18	6	13	14	20	25	28	39	30	27	22
33	25	8	0	0	22	6	14	14	22	26	27	40	31	27	23
34	27	8	0	0	21	7	14	14	22	26	27	40	30	26	21
35	26	4	0	0	19	7	14	16	19	22	26	40	29	27	19
36	26	4	0	0	15	7	13	17	20	23	26	41	26	26	20
37	27	4	0	1	12	7	13	18	21	23	26	41	26	27	22
38	29	3	0	1	7	7	14	18	22	24	26	40	25	29	23
39	28	1	0	1	5	8	13	19	20	23	26	40	23	29	22
40	29	1	0	1	5	8	14	18	22	21	26	38	26	29	22
41	28	2	0	1	4	8	14	17	22	22	26	36	26	26	22
42	29	1	0	1	3	7	14	16	23	19	26	35	28	27	21
43	29	2	0	0	2	7	12	17	23	18	28	35	28	28	21
44	30	2	0	1	1	8	14	18	23	20	28	34	29	27	19
45	31	2	0	1	1	9	15	19	24	20	28	34	30	26	20
46	30	2	0	1	3	9	15	19	24	20	29	34	29	23	20
47	24	2	0	1	3	11	15	18	23	21	31	33	29	24	20
48	21	2	0	0	3	11	13	18	21	23	31	33	29	24	19
49	22	1	0	0	3	12	13	18	22	23	30	31	29	24	17
50	20	1	0	0	3	9	12	17	22	22	31	30	28	23	16

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GIVEN FREQUENCY INDEX

401	451	501	551	601	651	701	751	801	851	901	951	1001
14	21	24	32	29	28	23	14	22	19	20	26	19
12	21	23	33	31	28	23	14	20	21	22	25	23
13	21	25	31	30	29	21	15	21	20	22	23	23
13	19	25	29	30	29	21	16	21	20	22	24	22
15	17	24	28	31	31	22	15	22	18	22	24	21
16	18	24	30	31	30	20	15	23	17	22	21	20
17	18	25	29	28	31	21	15	21	18	21	21	20
16	20	27	28	27	31	22	13	21	18	18	20	20
18	22	28	31	28	32	21	14	23	18	19	20	19
16	22	30	31	29	32	19	15	24	19	19	20	20
15	21	29	31	29	32	19	15	25	18	18	20	22
16	20	27	30	28	30	20	17	25	18	19	16	22
16	19	26	33	26	29	19	18	26	18	18	17	17
15	18	27	32	26	29	21	19	24	17	20	18	17
18	17	28	32	28	29	20	19	23	17	23	19	17
20	17	28	29	27	30	21	18	20	17	22	20	18
20	15	29	30	26	32	22	18	22	18	22	19	18
21	14	28	30	24	31	22	18	21	16	24	20	16
20	16	26	29	25	31	22	18	21	15	25	20	15
20	16	28	30	25	29	23	17	18	16	24	19	18
19	16	28	31	24	29	24	18	17	16	24	17	18
19	16	27	31	27	28	25	19	16	19	24	17	21
19	19	28	32	26	28	24	19	17	17	25	17	21
21	18	26	34	25	27	25	18	14	16	25	18	23
21	20	27	34	26	27	24	18	13	15	24	21	25
20	20	30	34	26	28	25	19	13	14	24	21	
20	19	30	36	27	27	25	19	14	14	21	21	
18	21	32	38	29	28	26	20	14	15	19	18	
18	22	30	38	29	28	26	20	15	14	18	19	
19	22	29	38	31	27	23	23	16	14	20	17	
18	24	28	39	28	26	23	26	16	12	20	19	
20	25	28	39	30	27	22	25	17	11	21	18	
22	26	27	40	31	27	23	22	17	12	20	20	
22	26	27	40	30	26	21	23	18	12	19	20	
19	22	26	40	29	27	19	27	17	13	18	19	
20	23	26	41	26	26	20	28	18	14	20	19	
21	23	26	41	26	27	22	28	19	14	17	18	
22	24	26	40	25	29	23	27	20	17	16	18	
20	23	26	40	23	29	22	28	19	18	15	18	
22	21	26	38	26	29	22	29	17	18	14	17	
22	22	26	36	26	26	22	27	16	18	17	17	
23	19	26	35	28	27	21	29	19	18	20	19	
23	18	28	35	28	28	21	28	20	18	22	21	
23	20	28	34	29	27	19	27	20	19	24	19	
24	20	28	34	30	26	20	29	20	19	26	19	
24	20	29	34	29	23	20	25	19	20	28	19	
23	21	31	33	29	24	20	23	17	18	27	17	
21	23	31	33	29	24	19	23	18	18	27	19	
22	23	30	31	29	24	17	24	18	18	27	20	
22	22	31	30	28	23	16	24	18	21	26	19	

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NUMBER OF SENSORS WITH SIGNAL LESS THAN NOISE AT GIVEN FREQUENCY INDEX

	1	51	101	151	201	251	301	351	401	451	501	551	601	651	701
1	51	32	2	2	0	0	0	0	0	0	0	0	1	4	0
2	51	27	2	1	0	0	0	0	0	0	0	0	1	5	1
3	51	25	1	1	0	0	0	0	0	0	0	0	1	5	0
4	52	22	1	1	0	0	0	0	0	0	0	0	1	5	1
5	52	20	2	1	0	0	0	0	0	0	0	0	2	4	1
6	51	17	2	1	0	0	0	0	0	0	0	0	2	3	1
7	51	13	2	1	0	0	0	1	0	0	1	0	1	2	3
8	50	8	2	2	0	0	0	0	0	0	0	0	1	2	3
9	49	7	2	2	0	0	0	0	0	0	0	1	1	2	2
10	49	7	2	1	0	0	0	0	0	0	0	0	1	2	2
11	50	5	2	0	0	0	0	0	0	1	0	0	1	3	2
12	49	6	2	1	0	0	0	0	0	0	0	0	1	3	3
13	49	5	3	1	0	0	0	0	0	0	0	0	1	2	4
14	52	5	3	1	0	0	0	0	0	0	0	0	1	2	3
15	52	3	2	1	0	0	0	0	0	0	0	0	1	2	3
16	50	3	2	1	0	0	0	0	0	0	0	0	1	3	2
17	50	2	2	0	0	0	0	2	0	0	0	0	1	4	3
18	48	2	4	0	0	0	0	1	0	0	0	0	0	3	2
19	51	2	4	0	0	0	0	0	0	0	0	0	0	3	2
20	51	2	3	0	0	0	0	0	0	0	0	1	0	2	2
21	54	2	3	0	0	0	0	0	0	0	0	0	0	2	1
22	53	2	3	0	0	0	0	0	0	0	0	0	0	2	2
23	54	2	3	0	0	0	0	0	0	0	0	0	0	2	3
24	54	1	2	0	0	0	0	0	0	0	0	0	0	3	2
25	54	1	1	0	0	0	0	0	0	0	0	0	0	3	2
26	54	0	1	0	0	0	0	0	0	0	0	0	1	3	2
27	58	0	1	0	0	0	0	0	0	0	0	0	1	4	3
28	61	0	2	0	0	0	0	0	0	0	0	0	2	3	3
29	60	0	3	0	0	0	0	0	0	0	0	0	2	3	2
30	59	0	3	0	0	0	0	0	0	0	0	0	1	2	4
31	62	0	4	0	0	0	0	0	0	0	0	0	1	1	5
32	59	0	3	0	0	0	0	0	0	0	0	0	2	2	7
33	59	0	3	0	0	0	0	0	0	0	0	0	2	2	5
34	58	0	2	0	0	0	0	0	0	0	0	0	0	2	3
35	57	0	3	0	0	0	0	0	0	0	0	0	0	3	1
36	59	0	3	0	0	0	1	0	0	0	0	0	0	2	0
37	57	0	4	0	0	0	0	0	0	0	0	0	0	3	0
38	56	0	4	0	0	0	0	0	0	0	0	1	0	4	1
39	51	0	3	0	0	0	0	1	0	0	0	1	0	4	1
40	47	0	3	0	0	0	0	1	0	0	0	1	1	1	2
41	47	0	2	0	0	0	0	0	0	0	0	2	0	1	1
42	46	0	2	0	0	0	0	0	0	0	0	0	1	2	1
43	44	0	2	0	0	0	0	0	0	0	1	0	1	0	0
44	45	0	2	0	0	0	0	0	0	0	0	0	2	1	0
45	43	0	2	0	0	0	0	0	0	0	0	0	2	1	0
46	40	2	2	0	0	0	0	0	0	0	0	1	3	0	0
47	36	2	2	0	0	0	0	0	0	0	0	0	3	0	1
48	34	2	3	0	0	0	0	0	0	0	0	1	5	0	2
49	36	2	3	0	0	0	0	0	0	0	0	1	6	0	2
50	35	2	2	0	0	0	0	0	0	0	0	1	6	0	2

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01	451	501	551	601	651	701	751	801	851	901	951	1001
0	0	0	0	1	4	0	2	7	8	12	8	8
0	0	0	0	1	5	1	2	8	9	13	8	8
0	0	0	0	1	5	0	4	5	8	12	8	7
0	0	0	0	1	5	1	3	5	7	10	7	7
0	0	0	0	2	4	1	3	7	7	9	7	7
0	0	0	0	2	3	1	3	7	7	9	7	7
0	0	1	0	1	2	3	1	9	7	8	8	8
0	0	0	0	1	2	3	2	7	7	7	9	8
0	0	0	1	1	2	2	2	5	5	7	10	10
0	0	0	0	1	2	2	2	5	6	9	8	11
0	1	0	0	1	3	2	1	6	6	8	8	10
0	0	0	0	1	3	3	3	7	8	7	9	9
0	0	0	0	1	2	4	3	7	8	6	8	9
0	0	0	0	1	2	3	3	7	10	6	9	9
0	0	0	0	1	2	3	4	7	11	5	8	10
0	0	0	0	1	3	2	3	6	9	7	8	11
0	0	0	0	1	4	3	5	6	11	8	8	10
0	0	0	0	0	3	2	5	6	11	8	9	14
0	0	0	0	0	3	2	4	6	11	7	10	13
0	0	0	1	0	2	2	5	7	12	6	10	14
0	0	0	0	0	2	1	3	7	10	7	11	18
0	0	0	0	0	2	2	4	7	11	8	9	17
0	0	0	0	0	2	3	4	8	13	10	8	15
0	0	0	0	0	3	2	4	8	15	7	8	15
0	0	0	0	0	3	2	3	9	15	8	10	15
0	0	0	0	1	3	2	1	7	14	9	8	
0	0	0	0	1	4	3	2	6	12	10	6	
0	0	0	0	2	3	3	2	10	12	9	7	
0	0	0	0	2	3	2	3	11	11	9	6	
0	0	0	0	1	2	4	5	12	11	9	6	
0	0	0	0	1	1	5	1	14	12	10	9	
0	0	0	0	2	2	7	2	13	12	12	10	
0	0	0	0	2	2	5	3	13	12	14	8	
0	0	0	0	0	2	3	2	13	11	14	7	
0	0	0	0	0	3	1	0	12	9	13	8	
0	0	0	0	0	2	0	1	14	10	15	8	
0	0	0	0	0	3	0	1	12	11	13	8	
0	0	0	1	0	4	1	1	8	11	9	7	
0	0	0	1	0	4	1	1	10	13	10	9	
0	0	0	1	1	1	2	3	12	14	11	8	
0	0	0	2	0	1	1	4	10	12	11	8	
0	0	0	0	1	2	1	5	8	10	10	9	
0	0	1	0	1	0	0	5	8	12	11	7	
0	0	0	0	2	1	0	4	6	11	12	4	
0	0	0	0	2	1	0	4	6	15	13	6	
0	0	0	1	3	0	0	3	4	13	12	6	
0	0	0	0	3	0	1	4	6	14	9	7	
0	0	0	1	5	0	2	4	7	14	9	8	
0	0	0	1	6	0	2	6	7	14	9	9	
0	0	0	1	6	0	2	6	6	12	8	8	

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NUMBER OF SENSORS WITH SIGNAL LESS THAN NOISE AT GIVEN FREQUENCY INDEX

	1	51	101	151	201	251	301	351	401	451	501	551	601	651	701
1	64	48	1	14	9	19	42	28	44	71	70	57	67	51	60
2	64	43	1	16	9	18	42	27	44	71	73	58	70	51	61
3	63	42	1	19	8	21	43	26	39	70	71	61	72	49	61
4	61	41	2	24	7	20	41	25	40	71	71	62	74	51	59
5	59	41	3	26	6	20	39	25	38	68	72	62	71	51	59
6	59	39	2	24	6	19	42	27	38	67	73	61	70	47	60
7	62	38	2	25	6	19	42	29	35	63	70	64	73	46	59
8	61	36	2	27	6	19	42	28	37	63	70	64	73	45	59
9	63	32	2	30	7	17	42	26	38	67	70	67	73	47	59
10	63	33	1	31	7	19	43	29	37	65	73	67	74	52	59
11	64	34	0	33	5	17	41	28	37	65	72	66	73	53	61
12	65	36	3	31	6	17	40	30	38	67	70	63	69	57	63
13	67	38	3	28	6	14	41	32	37	66	69	64	68	58	64
14	66	39	3	27	6	14	37	33	40	64	69	67	66	59	65
15	66	40	3	24	5	15	38	34	41	63	65	67	64	52	65
16	65	42	3	22	7	17	36	33	40	63	67	65	64	50	66
17	65	45	3	22	6	13	34	30	44	64	64	70	61	49	64
18	64	47	3	19	6	13	33	29	44	65	64	69	61	49	61
19	65	48	3	19	6	12	32	28	45	62	64	69	62	46	62
20	63	51	4	19	6	12	31	28	42	62	62	70	62	43	62
21	62	55	4	18	6	11	27	29	45	65	64	68	64	45	59
22	62	58	4	16	5	11	28	29	48	67	62	69	62	51	57
23	60	60	4	15	5	11	26	29	48	66	59	67	65	52	56
24	60	65	3	14	5	10	27	28	52	59	59	68	66	53	52
25	58	63	4	13	5	8	31	30	59	57	59	69	64	54	51
26	56	63	4	11	4	7	31	35	60	57	54	67	62	54	47
27	56	62	4	9	3	8	30	38	61	56	56	70	61	56	49
28	58	57	5	8	3	10	30	42	62	54	59	74	63	56	49
29	58	51	5	9	3	10	31	44	58	57	59	71	64	56	48
30	58	53	5	8	3	13	31	46	58	60	61	71	66	53	53
31	56	46	5	8	3	15	35	47	59	63	64	70	65	52	53
32	54	39	6	9	4	18	35	47	60	63	62	70	63	55	51
33	56	36	5	7	4	20	33	48	61	67	63	70	65	57	54
34	55	30	5	7	3	21	34	47	62	67	64	72	64	56	53
35	54	24	4	5	4	21	34	44	62	67	60	69	62	58	55
36	56	15	4	7	4	20	32	46	63	67	59	68	61	57	60
37	54	12	3	7	4	19	31	49	64	70	57	65	60	62	60
38	51	11	4	7	4	22	29	48	61	73	56	65	59	62	61
39	53	9	3	5	4	22	30	49	61	76	58	65	57	62	60
40	55	7	4	4	6	25	31	48	60	73	56	60	55	61	61
41	54	7	3	4	6	30	35	48	61	73	56	58	52	58	64
42	56	4	3	4	7	37	35	50	63	75	57	58	49	54	65
43	60	4	3	5	7	36	36	50	67	73	58	63	49	52	64
44	58	4	5	7	8	38	35	50	69	70	55	63	52	51	61
45	58	4	4	8	10	41	33	50	70	70	55	62	51	53	60
46	57	4	4	8	11	44	30	49	71	75	51	63	56	54	56
47	52	3	6	7	13	42	28	50	71	76	54	65	56	56	57
48	55	2	7	9	12	43	29	49	71	73	55	64	57	55	56
49	53	2	8	9	17	43	30	49	69	73	58	65	55	57	53
50	51	2	10	10	19	43	29	46	68	71	56	67	52	57	50

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GIVEN FREQUENCY INDEX

401	451	501	551	601	651	701	751	801	851	901	951	1001
44	71	70	57	67	51	60	48	56	43	43	39	43
44	71	73	58	70	51	61	48	53	46	42	39	44
39	70	71	61	72	49	61	49	55	44	42	41	43
40	71	71	62	74	51	59	50	53	43	44	43	44
38	68	72	62	71	51	59	52	52	42	43	40	46
38	67	73	61	70	47	60	51	49	47	42	40	45
35	63	70	64	73	46	59	52	51	41	45	41	44
37	63	70	64	73	45	59	49	55	41	45	44	43
38	67	70	67	73	47	59	52	54	40	43	44	45
37	65	73	67	74	52	59	56	52	40	40	44	43
37	65	72	66	73	53	61	56	51	41	43	43	46
38	67	70	63	69	57	63	54	52	42	45	43	45
37	66	69	64	68	58	64	53	48	39	50	40	45
40	64	69	67	66	59	65	55	46	40	50	45	45
41	63	65	67	64	52	65	54	44	36	48	46	42
40	63	67	65	64	50	66	54	45	36	47	43	39
44	64	64	70	61	49	64	49	46	38	50	41	47
44	65	64	69	61	49	61	53	43	36	51	44	51
45	62	64	69	62	46	62	53	42	37	53	45	52
42	62	62	70	62	43	62	52	40	38	51	47	50
45	65	64	68	64	45	59	54	40	36	52	43	50
48	67	62	69	62	51	57	54	38	35	53	39	50
48	66	59	67	65	52	56	54	41	36	52	40	50
52	59	59	68	66	53	52	55	40	37	52	39	50
59	57	59	69	64	54	51	55	41	40	51	38	50
60	57	54	67	62	54	47	54	40	41	50	40	
61	56	56	70	61	56	49	53	38	41	49	39	
62	54	59	74	63	56	49	48	40	40	49	42	
58	57	59	71	64	56	48	47	40	41	47	41	
58	60	61	71	66	53	53	45	38	42	49	40	
59	63	64	70	65	53	53	42	37	44	47	41	
60	63	62	70	63	55	51	42	32	42	51	40	
61	67	63	70	65	57	54	39	34	43	49	42	
62	67	64	72	64	56	53	39	33	43	48	41	
62	67	60	69	62	58	55	42	32	42	48	42	
63	67	59	68	61	57	60	44	30	43	45	42	
64	70	57	65	60	62	60	45	31	43	42	42	
61	73	56	65	59	62	61	45	32	44	40	42	
61	76	58	65	57	62	60	48	34	45	38	40	
60	73	56	60	55	61	61	46	35	46	37	38	
61	73	56	58	52	58	64	47	33	44	39	37	
63	75	57	58	49	54	65	49	32	42	37	38	
67	73	58	63	49	52	64	50	28	42	39	34	
69	70	55	63	52	51	61	50	30	44	40	36	
70	70	55	62	51	53	60	49	31	45	39	37	
71	75	51	63	56	54	56	48	37	46	37	43	
71	76	54	65	56	56	57	51	40	46	36	43	
71	73	55	64	57	55	56	49	41	45	37	43	
69	73	58	65	55	57	53	52	43	45	40	43	
68	71	56	67	52	57	50	52	44	48	38	40	

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NUMBER OF SENSORS WITH SIGNAL LESS THAN NOISE AT GIVEN FREQUENCY INDEX

	1	51	101	151	201	251	301	351	401	451	501	551	601	651	701
1	40	12	0	0	0	0	12	0	11	2	3	5	12	10	12
2	40	10	0	0	0	0	10	0	13	2	3	5	12	11	11
3	39	6	0	0	0	1	8	0	13	2	5	5	12	10	13
4	40	6	0	0	0	1	5	0	12	2	3	6	11	10	12
5	39	5	0	0	0	0	1	0	10	2	4	5	9	11	12
6	43	3	0	0	0	1	0	0	7	1	4	4	9	9	12
7	43	3	0	0	0	2	0	0	6	1	4	4	9	8	11
8	43	3	0	0	0	2	1	0	4	1	4	4	10	8	9
9	43	1	0	0	0	0	0	0	7	1	6	5	9	9	10
10	41	1	0	0	0	0	1	0	8	1	5	5	10	9	9
11	41	1	0	0	1	0	1	0	8	1	6	4	11	8	9
12	40	1	0	0	2	1	0	1	8	1	7	5	11	7	10
13	40	0	0	0	2	1	0	1	7	2	9	4	11	6	9
14	41	0	0	0	1	0	0	2	9	1	10	3	13	7	9
15	43	0	0	1	2	0	0	1	9	1	11	3	14	6	12
16	43	0	0	0	2	0	0	1	8	1	13	3	14	6	13
17	40	0	0	0	1	0	0	0	9	1	14	4	14	5	11
18	43	0	0	0	0	0	0	0	9	0	15	6	14	4	11
19	40	0	0	0	0	0	0	0	11	1	16	6	13	4	11
20	38	0	0	0	0	0	0	0	11	1	18	5	16	3	11
21	38	0	0	0	0	0	0	0	9	1	17	4	17	3	13
22	36	0	0	1	0	0	0	0	11	2	16	4	18	3	12
23	34	0	0	0	0	0	1	0	8	2	14	4	17	4	10
24	36	0	0	0	0	0	1	0	10	1	12	4	16	5	9
25	36	0	0	0	0	0	1	0	8	2	11	4	15	5	9
26	36	0	0	0	0	0	0	0	7	3	13	3	14	5	12
27	34	0	0	0	0	0	0	0	6	3	13	2	14	5	12
28	36	0	0	0	0	0	0	0	6	3	15	4	14	4	11
29	36	0	0	0	0	0	0	0	7	2	15	3	15	4	10
30	34	0	0	0	0	0	0	0	6	3	10	3	12	4	8
31	34	0	0	0	1	0	0	0	6	3	11	4	12	1	8
32	32	0	0	0	1	0	0	0	5	3	8	4	10	2	8
33	34	0	0	0	1	0	0	0	4	1	7	5	10	3	9
34	34	0	0	0	3	0	0	0	3	1	7	6	10	3	9
35	35	0	0	0	0	0	0	0	4	2	6	6	11	3	9
36	35	0	0	0	0	0	0	0	3	2	6	5	10	3	9
37	36	0	0	0	0	0	0	0	2	2	6	7	9	5	9
38	36	0	0	0	0	0	0	0	2	1	6	6	8	6	12
39	34	0	0	0	0	0	0	1	2	1	5	7	8	7	13
40	32	0	0	0	0	0	0	2	2	1	4	7	8	7	13
41	31	0	1	0	0	0	0	4	2	2	4	7	8	7	11
42	34	0	0	0	0	2	0	3	2	2	3	8	9	9	9
43	33	0	0	0	0	3	0	3	3	1	2	7	7	9	10
44	31	0	0	0	0	4	0	3	3	1	2	8	7	8	7
45	29	0	0	0	0	7	0	3	3	1	2	8	7	10	7
46	26	0	0	0	0	10	0	4	3	1	4	9	7	11	6
47	25	0	0	0	0	15	0	4	2	1	4	9	8	11	6
48	23	0	1	0	0	20	0	5	2	1	5	10	9	11	4
49	21	0	1	0	0	19	0	6	2	2	5	11	10	10	7
50	16	0	0	0	0	16	0	6	2	3	6	10	9	11	7

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IVEN FREQUENCY INDEX

01	451	501	551	601	651	701	751	801	851	901	951	1001
11	2	3	5	12	10	12	7	7	2	4	6	5
13	2	3	5	12	11	11	8	8	2	4	7	6
13	2	5	5	12	10	13	5	9	2	5	6	6
12	2	3	6	11	10	12	4	8	3	5	6	4
10	2	4	5	9	11	12	3	7	3	4	8	3
7	1	4	4	9	9	12	3	7	3	5	7	3
6	1	4	4	9	8	11	3	7	3	5	9	3
4	1	4	4	10	8	9	5	6	3	4	9	3
7	1	6	5	9	9	10	5	4	4	5	8	3
8	1	5	5	10	9	9	6	3	4	6	8	3
8	1	6	4	11	8	9	5	3	4	6	6	3
8	1	7	5	11	7	10	6	3	5	6	7	3
7	2	9	4	11	6	9	6	3	4	6	6	6
9	1	10	3	13	7	9	6	5	4	5	5	7
9	1	11	3	14	6	12	6	5	4	5	5	10
8	1	13	3	14	6	13	6	4	4	6	5	11
9	1	14	4	14	5	11	7	4	6	7	4	9
9	0	15	6	14	4	11	7	4	6	8	4	10
11	1	16	6	13	4	11	6	5	7	7	3	11
11	1	18	5	16	3	11	6	5	7	7	2	11
9	1	17	4	17	3	13	6	6	7	7	1	13
11	2	16	4	18	3	12	6	6	8	8	2	16
8	2	14	4	17	4	10	4	7	7	8	4	18
10	1	12	4	16	5	9	2	7	8	8	5	18
8	2	11	4	15	5	9	3	8	8	8	5	19
7	3	13	3	14	5	12	2	9	7	8	4	
6	3	13	2	14	5	12	2	9	7	6	4	
6	3	15	4	14	4	11	5	9	6	6	4	
7	2	15	3	15	4	10	5	10	6	7	6	
6	3	10	3	12	4	8	5	10	4	7	5	
6	3	11	4	12	1	8	5	9	6	7	7	
5	3	8	4	10	2	8	5	8	6	8	7	
4	1	7	5	10	3	9	6	10	6	9	7	
3	1	7	6	10	3	9	6	9	6	8	6	
4	2	6	6	11	3	9	6	9	6	7	6	
3	2	6	5	10	3	9	7	10	5	8	6	
2	2	6	7	9	5	9	5	9	5	8	5	
2	1	6	6	8	6	12	4	10	5	5	6	
2	1	5	7	8	7	13	3	10	5	4	6	
2	1	4	7	8	7	13	2	10	3	5	5	
2	2	4	7	8	7	11	2	10	3	9	5	
2	2	3	8	9	9	9	2	10	3	7	5	
3	1	2	7	7	9	10	2	9	4	5	5	
3	1	2	8	7	8	7	3	8	4	5	5	
3	1	2	8	7	10	7	3	7	4	6	5	
3	1	4	9	7	11	6	4	6	1	5	6	
2	1	4	9	8	11	6	6	5	2	4	6	
2	1	5	10	9	11	4	7	5	3	4	6	
2	2	5	11	10	10	7	7	6	4	5	6	
2	3	6	10	9	11	7	7	4	4	6	6	

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OFFICE ELECTRONICS INC.

NUMBER OF SENSORS WITH SIGNAL LESS THAN NOISE AT GIVEN FREQUENCY INDEX

	1	51	101	151	201	251	301	351	401	451	501	551	601	651	701
1	44	38	40	37	6	0	0	5	1	1	11	5	6	9	19
2	44	38	36	32	5	0	0	5	1	1	11	5	9	9	18
3	45	37	36	30	5	0	0	3	2	1	11	5	9	8	20
4	45	38	36	28	5	0	0	4	2	1	11	3	10	9	19
5	45	40	38	28	5	0	0	4	2	2	11	3	8	8	19
6	44	41	40	26	5	0	0	4	2	3	10	3	8	9	20
7	45	43	42	26	3	0	0	4	2	3	9	3	8	8	21
8	45	46	41	26	3	0	0	6	2	3	8	4	8	7	21
9	44	44	42	25	4	0	0	5	2	3	8	4	7	7	20
10	45	43	39	26	4	0	1	5	2	3	9	5	7	7	19
11	43	42	37	25	4	0	1	5	2	3	10	7	6	8	18
12	42	42	35	28	3	0	1	5	2	4	9	7	5	7	16
13	42	39	36	29	4	0	2	5	2	4	9	6	5	8	15
14	42	40	37	26	4	0	3	5	1	3	9	7	5	8	17
15	42	36	33	25	4	0	2	5	1	3	10	9	5	8	16
16	43	35	33	25	3	0	2	6	1	3	10	7	6	10	18
17	43	34	31	24	3	0	1	6	1	3	9	7	6	9	18
18	45	33	30	24	3	1	1	4	1	3	9	6	6	11	18
19	46	33	32	24	4	1	1	4	3	4	11	7	6	11	17
20	45	34	32	24	3	1	1	3	4	4	11	8	4	11	16
21	46	35	33	24	3	1	1	3	4	5	12	8	5	12	18
22	46	35	32	23	2	1	1	3	5	6	13	8	5	10	20
23	46	36	36	22	2	1	1	4	5	7	13	10	6	10	20
24	46	34	36	22	1	1	2	4	5	8	11	9	6	11	21
25	44	35	35	20	0	1	2	5	5	8	9	8	6	14	20
26	41	37	35	18	0	1	2	5	7	8	11	9	5	13	21
27	40	39	36	18	0	1	2	5	6	7	11	9	7	12	21
28	42	39	37	19	0	1	2	5	6	8	11	8	8	12	23
29	44	40	34	18	2	1	2	7	3	10	9	9	8	14	25
30	45	39	33	15	2	1	2	6	2	9	9	9	8	14	24
31	43	40	35	13	1	1	2	6	3	11	9	8	7	13	24
32	45	37	34	11	1	1	3	5	2	14	9	8	9	12	21
33	46	37	35	11	2	2	6	6	1	13	8	8	8	11	21
34	47	38	36	9	2	2	7	4	2	10	9	8	7	10	20
35	46	41	34	8	2	2	7	4	4	9	10	7	8	10	20
36	48	41	33	7	2	2	6	4	5	10	9	7	8	10	17
37	47	45	32	7	2	0	7	3	5	10	9	7	9	11	17
38	45	40	30	7	0	0	7	3	6	9	9	8	8	11	16
39	43	43	26	6	0	0	9	4	5	10	9	8	7	14	17
40	44	41	27	6	0	0	10	4	5	10	10	8	7	15	18
41	43	42	29	5	0	0	9	4	3	10	7	9	7	13	21
42	44	39	29	6	1	0	10	4	3	9	7	10	9	13	21
43	44	37	31	7	1	0	8	6	3	8	8	10	9	12	18
44	45	35	33	6	1	0	7	6	3	8	5	10	7	13	19
45	45	34	35	6	1	0	7	6	2	9	6	11	9	14	20
46	43	35	34	7	1	0	7	4	2	10	6	10	11	17	22
47	43	34	34	6	1	0	7	2	2	10	5	10	12	17	23
48	41	35	37	6	1	0	7	1	1	10	4	10	11	20	22
49	40	38	37	6	0	0	5	1	1	10	5	8	11	18	21
50	40	39	38	6	0	0	4	1	1	9	5	7	12	19	22

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GIVEN FREQUENCY INDEX

401	451	501	551	601	651	701	751	801	851	901	951	1001
1	1	11	5	6	9	19	24	28	21	21	27	30
1	1	11	5	9	9	18	23	26	21	22	25	30
2	1	11	5	9	8	20	25	29	23	23	26	32
2	1	11	3	10	9	19	26	29	21	23	29	32
2	2	11	3	8	8	19	28	27	21	23	29	30
2	3	10	3	8	9	20	27	25	22	22	30	29
2	3	9	3	8	8	21	26	25	18	22	30	29
2	3	8	4	8	7	21	24	26	19	23	30	28
2	3	8	4	7	7	20	24	25	21	22	29	31
2	3	9	5	7	7	19	22	25	23	23	26	30
2	3	10	7	6	8	18	23	24	24	25	25	33
2	4	9	7	5	7	16	24	26	25	21	23	32
2	4	9	6	5	8	15	24	27	27	20	22	32
1	3	9	7	5	8	17	21	26	29	19	22	30
1	3	10	9	5	8	16	21	26	31	23	22	28
1	3	10	7	6	10	18	24	28	30	23	23	29
1	3	9	7	6	9	18	25	28	28	22	24	30
1	3	9	6	6	11	18	24	28	26	23	24	30
3	4	11	7	6	11	17	22	30	29	25	25	32
4	4	11	8	4	11	16	23	31	26	25	25	31
4	5	12	8	5	12	18	24	34	27	25	27	31
5	6	13	8	5	10	20	22	34	29	25	28	30
5	7	13	10	6	10	20	21	35	29	25	25	28
5	8	11	9	6	11	21	23	35	29	26	23	28
5	8	9	8	6	14	20	22	35	27	29	23	28
7	8	11	9	5	13	21	22	36	27	28	22	
6	7	11	9	7	12	21	22	32	28	25	24	
6	8	11	8	8	12	23	21	33	29	25	26	
3	10	9	9	8	14	25	16	35	30	28	29	
2	9	9	9	8	14	24	18	34	27	29	29	
3	11	9	8	7	13	24	18	32	27	29	29	
2	14	9	8	9	12	21	20	30	30	29	29	
1	13	8	8	8	11	21	21	28	32	29	26	
2	10	9	8	7	10	20	22	28	31	29	26	
4	9	10	7	8	10	20	19	27	34	29	27	
5	10	9	7	8	10	17	21	25	34	29	28	
5	10	9	7	9	11	17	22	23	36	28	29	
6	9	9	8	8	11	16	23	22	34	28	30	
5	10	9	8	7	14	17	26	22	35	26	31	
5	10	10	8	7	15	18	25	20	35	28	32	
3	10	7	9	7	13	21	25	19	34	28	33	
3	9	7	10	9	13	21	24	22	29	28	30	
3	8	8	10	9	12	18	26	22	29	30	29	
3	8	5	10	7	13	19	26	23	28	30	30	
2	9	6	11	9	14	20	26	22	30	31	28	
2	10	6	10	11	17	22	26	21	30	31	27	
2	10	5	10	12	17	23	26	23	29	29	28	
1	10	4	10	11	20	22	23	22	24	30	30	
1	10	5	8	11	18	21	27	22	24	29	30	
1	9	5	7	12	19	22	27	23	23	27	30	

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EVENT 77

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A= 0.0 ON CHANNEL 125

A= 0.0 ON CHANNEL 126
NUMBER OF SENSORS WITH SIGNAL LESS THAN NOISE AT GIVEN FREQUENCY INDEX

	1	51	101	151	201	251	301	351	401	451	501	551	601	651	701
1	60	20	25	1	43	43	46	49	51	49	52	62	53	49	50
2	60	16	29	2	44	43	45	49	54	48	52	62	51	46	47
3	59	16	35	1	45	44	45	53	53	48	52	62	48	44	46
4	59	17	38	1	47	45	44	50	54	50	50	65	47	44	49
5	60	15	45	1	45	46	46	50	57	52	49	64	49	46	50
6	61	9	45	1	46	47	48	50	58	56	50	66	52	47	54
7	63	9	46	2	48	48	49	50	62	59	49	66	54	50	52
8	62	8	49	2	51	52	52	51	62	60	52	66	55	51	51
9	61	7	48	2	50	50	54	49	61	62	54	65	57	51	51
10	61	8	40	2	45	49	55	50	60	62	53	64	56	48	52
11	61	6	37	4	47	49	54	51	61	60	51	61	55	49	51
12	60	4	31	4	46	48	57	51	59	61	48	58	55	53	53
13	58	2	27	4	42	48	56	53	57	61	48	58	56	54	54
14	57	1	26	4	41	49	53	54	58	60	48	55	57	52	55
15	55	1	23	4	37	48	53	55	59	63	51	54	57	50	55
16	55	1	24	4	33	51	53	53	61	60	52	54	54	51	56
17	54	1	23	4	33	51	57	53	60	62	51	52	51	53	54
18	57	1	21	5	30	50	61	53	62	59	52	52	51	52	55
19	59	1	19	5	29	52	55	54	60	59	53	51	51	53	53
20	59	1	19	6	28	49	57	56	60	58	52	49	54	54	49
21	58	1	19	6	27	48	56	53	63	58	54	50	53	54	49
22	57	1	16	6	29	49	59	54	64	59	55	49	54	52	51
23	56	1	16	5	29	51	55	53	64	59	58	50	53	49	53
24	55	1	15	5	30	54	56	56	61	54	54	50	52	51	55
25	51	1	17	6	31	55	55	57	62	52	55	50	51	52	53
26	54	1	15	6	30	59	56	57	64	49	56	51	50	54	52
27	54	1	12	5	28	55	55	56	62	49	57	51	50	53	51
28	55	1	13	6	30	59	52	57	59	48	57	50	51	57	48
29	54	1	13	6	32	57	49	58	59	45	58	49	51	52	49
30	53	1	13	5	30	55	50	57	56	45	61	51	48	53	48
31	51	2	11	5	32	56	49	58	54	44	60	54	47	54	50
32	48	2	10	4	34	53	50	55	53	45	62	54	45	57	48
33	45	2	9	6	36	54	51	51	52	48	64	55	49	58	49
34	42	2	9	9	38	54	47	51	53	50	64	57	50	62	51
35	43	2	10	10	38	53	47	49	51	50	62	58	50	61	52
36	45	2	10	11	37	51	47	47	52	50	61	59	51	60	51
37	45	3	9	14	39	49	46	49	52	50	62	60	50	56	53
38	43	3	7	17	39	49	50	49	55	48	63	58	50	56	57
39	42	3	7	19	39	49	51	51	56	50	64	54	50	55	53
40	41	3	5	20	37	54	49	49	56	50	63	55	52	55	54
41	40	3	5	22	36	53	51	48	57	52	60	55	47	56	54
42	37	3	3	22	36	50	53	45	55	52	61	56	47	56	53
43	34	2	3	26	37	49	53	43	53	49	60	56	45	55	52
44	33	4	3	25	38	49	53	41	52	49	57	56	45	55	52
45	31	7	3	25	37	51	50	43	55	46	58	57	49	58	49
46	26	9	3	31	36	52	49	43	55	46	58	58	50	55	47
47	24	12	2	29	41	51	51	44	52	47	58	58	49	54	49
48	27	14	2	32	40	50	52	46	49	52	59	55	51	54	47
49	21	21	1	36	42	49	54	48	48	53	58	57	52	52	45
50	20	23	1	43	43	51	51	47	47	52	58	56	52	52	45

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GIVEN FREQUENCY INDEX

401	451	501	551	601	651	701	751	801	851	901	951	1001
51	49	52	62	53	49	50	45	44	35	44	41	36
54	48	52	62	51	46	47	42	42	36	42	41	38
53	48	52	62	48	44	46	43	40	36	44	37	37
54	50	50	65	47	44	49	42	41	36	42	36	36
57	52	49	64	49	46	50	40	40	36	41	34	35
58	56	50	66	52	47	54	42	40	35	37	35	36
62	59	49	66	54	50	52	43	41	31	37	34	35
62	60	52	66	55	51	51	46	41	31	38	34	32
61	62	54	65	57	51	51	45	43	32	40	36	29
60	62	53	64	56	48	52	44	45	32	42	36	31
61	60	51	61	55	49	51	44	41	32	43	39	30
59	61	48	58	55	53	53	42	45	32	41	36	30
57	61	48	58	56	54	54	40	46	34	40	36	31
58	60	48	55	57	52	55	37	46	37	37	34	34
59	63	51	54	57	50	55	33	48	37	39	37	36
61	60	52	54	54	51	56	32	51	37	42	36	36
60	62	51	52	51	53	54	34	47	36	38	37	35
62	59	52	52	51	52	55	33	45	37	36	34	36
60	59	53	51	51	53	53	32	44	39	34	34	38
60	58	52	49	54	54	49	34	43	38	35	34	40
63	58	54	50	53	54	49	35	44	38	34	33	42
64	59	55	49	54	52	51	34	42	39	36	31	42
64	59	58	50	53	49	53	35	43	37	36	34	43
61	54	54	50	52	51	55	36	42	37	36	36	44
62	52	55	50	51	52	53	35	43	38	36	36	45
64	49	56	51	50	54	52	34	45	37	36	36	
62	49	57	51	50	53	51	36	48	37	36	32	
59	48	57	50	51	57	48	38	46	35	35	33	
59	45	58	49	51	52	49	43	45	36	35	32	
56	45	61	51	48	53	48	46	44	36	36	32	
54	44	60	54	47	54	50	49	46	35	36	30	
53	45	62	54	45	57	48	53	45	33	37	29	
52		64	55	49	58	49	53	45	33	40	30	
53	50	64	57	50	62	51	51	41	33	42	34	
51	50	62	58	50	61	52	50	39	34	40	34	
52	50	61	59	51	60	51	50	37	38	40	34	
52	50	62	60	50	56	53	50	39	37	38	31	
55	48	63	58	50	56	57	51	40	38	39	33	
56	50	64	54	50	55	53	52	40	38	42	38	
56	50	63	55	52	55	54	54	38	36	41	36	
57	52	60	55	47	56	54	54	35	37	45	33	
55	52	61	56	47	56	53	54	34	39	46	34	
53	49	60	56	45	55	52	52	35	40	46	34	
52	49	57	56	45	55	52	52	35	41	44	33	
55	46	58	57	49	58	49	53	34	43	46	33	
55	46	58	58	50	55	47	49	32	45	47	32	
52	47	58	58	49	54	49	48	32	46	48	30	
49	52	59	55	51	54	47	47	32	44	45	32	
48	53	58	57	52	52	45	45	34	42	44	33	
47	52	58	56	52	52	45	43	35	42	41	35	

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NUMBER OF SENSORS WITH SIGNAL LESS THAN NOISE AT GIVEN FREQUENCY INDEX

	1	51	101	151	201	251	301	351	401	451	501	551	601	651	701
1	58	1	0	9	5	0	9	7	14	30	45	29	44	23	21
2	58	1	0	4	5	0	13	6	13	26	48	27	39	22	20
3	58	1	0	2	7	0	14	6	14	25	47	28	33	26	19
4	58	1	0	1	6	2	15	6	14	24	48	27	34	26	19
5	59	1	0	0	5	2	14	6	14	23	45	27	33	22	19
6	59	1	0	0	4	2	16	6	11	23	44	25	33	25	18
7	62	1	0	0	3	1	18	5	10	26	42	27	37	25	19
8	62	1	0	1	4	2	16	6	10	26	37	28	39	25	19
9	64	1	0	1	4	4	11	5	13	26	39	31	39	22	17
10	65	2	0	1	1	5	11	7	12	28	37	34	38	22	15
11	64	2	0	2	1	5	9	7	12	29	36	35	38	20	16
12	63	1	0	2	1	4	9	6	12	28	34	34	40	20	15
13	63	0	0	2	1	4	8	5	12	30	29	34	40	20	12
14	62	0	0	1	1	3	9	5	12	29	29	34	39	21	10
15	63	0	0	1	1	3	10	5	12	32	30	34	40	21	11
16	63	0	0	1	3	3	10	4	11	36	31	36	39	21	10
17	59	0	0	2	3	2	11	4	11	36	30	35	38	22	11
18	60	0	0	2	3	1	12	4	13	38	30	38	33	21	12
19	61	0	0	2	2	1	12	2	12	37	28	37	33	18	13
20	61	0	0	1	2	1	10	2	12	35	27	39	33	18	13
21	60	0	0	0	2	2	10	4	15	41	26	40	32	21	15
22	59	0	0	0	2	3	10	5	15	41	25	40	32	20	15
23	60	0	0	0	2	4	9	5	15	41	28	39	30	17	15
24	61	0	0	0	2	5	9	5	17	39	30	39	32	19	14
25	57	0	0	0	1	5	9	5	17	41	32	41	35	19	15
26	55	0	0	0	0	3	11	5	18	37	32	40	35	17	16
27	54	0	0	0	0	3	11	5	21	38	32	36	37	15	15
28	53	1	0	0	0	4	11	5	22	37	35	35	36	16	17
29	47	1	0	0	0	4	10	6	23	36	33	34	36	16	16
30	36	1	0	0	0	3	11	6	25	35	33	33	34	17	17
31	30	1	0	0	1	3	11	6	29	35	34	33	35	18	15
32	29	2	0	0	4	3	11	6	28	32	33	36	35	16	14
33	22	2	0	0	5	2	8	7	26	31	32	37	36	14	14
34	17	3	0	0	5	3	6	9	25	32	35	39	36	14	14
35	15	2	0	0	5	2	8	9	27	31	31	41	35	14	15
36	12	2	1	0	5	1	10	12	28	29	29	39	34	15	15
37	10	2	1	0	3	1	13	14	28	29	28	38	35	17	17
38	9	1	1	0	2	2	13	15	30	32	30	39	35	18	17
39	6	2	1	0	2	0	13	14	33	34	30	37	34	18	15
40	5	2	4	0	3	0	14	14	32	36	30	39	31	17	15
41	4	2	7	0	3	0	13	14	33	39	30	39	29	16	16
42	4	1	8	1	2	1	16	14	33	40	33	37	26	17	19
43	2	1	10	1	2	1	12	15	32	39	34	42	23	17	19
44	1	1	15	1	2	2	13	14	37	38	34	40	22	18	18
45	1	1	19	1	1	2	11	15	39	39	30	40	22	18	17
46	1	0	22	3	1	3	13	14	38	40	30	41	24	18	17
47	1	0	23	3	1	4	13	14	33	42	29	43	27	19	15
48	1	0	22	3	1	6	10	14	35	42	28	47	25	20	14
49	1	0	15	4	1	6	9	15	35	45	31	46	27	21	15
50	1	0	16	3	1	10	8	13	31	44	29	46	25	20	15

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GIVEN FREQUENCY INDEX

401	451	501	551	601	651	701	751	801	851	901	951	1001
14	30	45	29	44	23	21	14	12	15	14	13	8
13	26	48	27	39	22	20	14	14	12	14	16	10
14	25	47	28	33	26	19	12	13	12	13	16	10
14	24	48	27	34	26	19	12	11	13	14	18	11
14	23	45	27	33	22	19	14	11	11	12	18	10
11	23	44	25	33	25	18	15	11	12	12	17	10
10	26	42	27	37	25	19	15	10	12	12	17	12
10	26	37	28	39	25	19	16	11	11	13	17	13
13	26	39	31	39	22	17	18	11	11	11	17	12
12	28	37	34	38	22	15	18	10	12	10	16	13
12	29	36	35	38	20	16	22	12	12	10	15	15
12	28	34	34	40	20	15	22	11	13	9	15	14
12	30	29	34	40	20	12	22	11	14	8	16	15
12	29	29	34	39	21	10	19	11	15	8	16	16
12	32	30	34	40	21	11	18	13	17	8	16	16
11	36	31	36	39	21	10	17	13	18	8	18	15
11	36	30	35	38	22	11	15	13	18	7	18	16
13	38	30	38	33	21	12	14	11	17	7	17	17
12	37	28	37	33	18	13	18	11	16	8	17	17
12	35	27	39	33	18	13	18	11	18	9	17	18
15	41	26	40	32	21	15	17	8	18	10	15	19
15	41	25	40	32	20	15	16	10	15	10	17	18
15	41	28	39	30	17	15	16	9	14	9	19	19
17	39	30	39	32	19	14	17	9	14	10	19	21
17	41	32	41	35	19	15	16	9	14	12	18	21
18	37	32	40	35	17	16	16	8	16	13	18	
21	38	32	36	37	15	15	16	7	18	13	17	
22	37	35	35	36	16	17	16	9	19	15	15	
23	36	33	34	36	16	16	16	9	17	16	14	
25	35	33	33	34	17	17	18	10	18	16	13	
29	35	34	33	35	18	15	19	8	18	14	12	
28	32	33	36	35	16	14	20	8	18	14	12	
26	31	32	37	36	14	14	20	11	17	15	12	
25	32	35	39	36	14	14	21	11	16	15	12	
27	31	31	41	35	14	15	20	11	14	16	15	
28	29	29	39	34	15	15	20	13	14	16	15	
28	29	28	38	35	17	17	19	10	12	18	16	
30	32	30	39	35	18	17	19	8	13	20	16	
33	34	30	37	34	18	15	19	8	16	19	16	
32	36	30	39	31	17	15	19	8	13	15	17	
33	39	30	39	29	16	16	17	8	12	14	16	
33	40	33	37	26	17	19	14	9	12	13	14	
32	39	34	42	23	17	19	15	9	12	14	15	
37	38	34	40	22	18	18	16	9	12	12	15	
39	39	30	40	22	18	17	16	10	11	13	13	
38	40	30	41	24	18	17	18	9	11	14	10	
33	42	29	43	27	19	15	18	8	11	12	8	
35	42	28	47	25	20	14	16	9	9	13	10	
35	45	31	46	27	21	15	16	10	8	13	11	
31	44	29	46	25	20	15	15	12	12	12	10	

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NUMBER OF SENSORS WITH SIGNAL LESS THAN NOISE AT GIVEN FREQUENCY INDEX

	1	51	101	151	201	251	301	351	401	451	501	551	601	651	701
1	29	30	4	23	11	21	17	33	35	27	31	36	29	32	23
2	29	27	4	22	12	21	15	33	35	28	31	36	29	32	21
3	29	28	4	21	11	19	18	34	35	29	32	38	29	33	23
4	30	30	3	20	11	20	19	34	35	29	31	39	31	33	26
5	30	25	3	22	13	20	18	35	36	29	31	39	29	34	27
6	30	22	4	22	12	20	19	35	37	32	26	39	30	33	26
7	31	20	[illegible]	20	12	20	20	36	36	32	27	36	29	31	26
8	30	20	[illegible]	22	12	23	20	37	36	33	27	36	27	28	27
9	30	19	[illegible]	21	12	23	25	36	35	33	29	35	29	27	29
10	29	19	5	21	11	21	29	36	36	30	31	35	29	28	29
11	29	18	4	18	11	24	29	32	36	30	30	33	29	27	32
12	29	19	3	21	11	26	32	31	35	31	30	33	30	27	30
13	27	20	3	22	11	31	34	30	33	32	29	33	29	26	30
14	27	19	3	22	11	31	32	31	30	31	30	35	29	25	28
15	27	18	4	21	11	31	35	30	32	32	31	34	28	24	28
16	27	18	4	19	11	31	33	31	33	32	28	35	30	25	28
17	28	18	4	22	11	31	29	32	33	30	31	35	30	27	26
18	29	18	5	18	9	30	26	33	32	31	33	33	30	28	29
19	28	18	5	20	9	28	26	32	32	33	32	33	31	29	29
20	29	18	7	19	9	31	23	33	33	32	30	35	33	30	29
21	29	17	8	19	8	33	23	32	32	31	29	32	33	29	30
22	30	17	8	19	11	30	22	29	33	31	30	32	30	29	31
23	29	14	7	19	14	28	23	27	30	33	29	32	31	32	30
24	30	14	7	19	16	26	24	28	30	35	27	32	30	30	32
25	31	14	7	22	16	26	23	27	30	34	27	29	30	31	29
26	32	16	6	23	19	26	22	28	31	36	25	27	31	30	26
27	33	19	7	22	21	25	21	29	29	35	26	26	31	30	27
28	33	20	9	22	26	24	23	32	30	35	25	28	33	30	27
29	34	25	11	24	27	24	24	29	32	34	25	29	33	28	27
30	32	28	14	23	27	23	26	33	31	35	26	29	33	28	26
31	27	31	18	24	24	25	26	34	31	33	31	28	34	28	26
32	27	32	19	22	21	26	26	33	28	32	32	29	32	29	23
33	29	34	21	22	19	28	24	34	30	34	32	28	37	30	21
34	28	33	22	23	17	29	25	33	31	35	35	28	33	32	18
35	28	35	24	24	16	28	24	29	31	34	33	27	38	30	19
36	26	36	26	26	16	30	22	30	30	32	34	26	35	31	19
37	27	37	28	29	14	28	20	29	30	33	34	25	33	31	17
38	23	38	27	31	14	28	21	33	30	34	33	27	33	30	17
39	27	40	32	36	13	27	24	31	31	34	35	27	36	31	17
40	30	35	35	39	13	26	26	30	30	37	37	28	37	31	19
41	30	27	35	38	13	30	27	29	28	34	36	28	39	31	19
42	32	20	34	36	13	29	25	29	23	31	37	27	39	30	19
43	32	14	35	32	14	28	25	29	25	31	34	26	38	30	22
44	32	11	34	26	17	29	23	29	27	31	35	25	35	31	23
45	35	9	33	21	16	30	23	32	25	32	36	24	33	30	26
46	35	8	32	20	18	27	24	34	26	31	36	27	32	29	28
47	34	5	27	18	19	27	24	37	25	32	38	27	33	24	29
48	34	2	28	17	22	25	25	36	26	33	36	28	34	24	30
49	33	3	28	15	24	22	29	38	27	31	37	29	31	24	31
50	31	3	26	13	21	20	32	39	28	30	37	30	32	23	31

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GIVEN FREQUENCY INDEX

401	451	501	551	601	651	701	751	801	851	901	951	1001
35	27	31	36	29	32	23	31	33	28	27	24	28
35	28	31	36	29	32	21	29	31	28	27	25	27
35	29	32	38	29	33	23	28	30	29	29	27	26
35	29	31	39	31	33	26	28	31	30	29	28	27
36	29	31	39	29	34	27	27	30	28	32	30	26
37	32	26	39	30	33	26	26	28	29	31	27	26
36	32	27	36	29	31	26	25	29	29	29	28	26
36	33	27	36	27	28	27	25	30	29	26	27	22
35	33	29	35	29	27	29	26	30	31	22	27	21
36	30	31	35	29	28	29	26	29	32	23	27	22
36	30	30	33	29	27	32	25	28	31	23	23	23
35	31	30	33	30	27	30	27	29	30	24	23	24
33	32	29	33	29	26	30	28	28	30	24	22	24
30	31	30	35	29	25	28	26	27	32	26	24	24
32	32	31	34	28	24	28	27	28	33	25	26	23
33	32	28	35	30	25	28	28	28	31	25	25	23
33	30	31	35	30	27	26	28	27	30	23	26	23
32	31	33	33	30	28	29	30	27	29	22	27	25
32	33	32	33	31	29	29	31	25	30	22	26	26
33	32	30	35	33	30	29	33	24	31	23	26	26
32	31	29	32	33	29	30	33	24	33	22	27	28
33	31	30	32	30	29	31	33	23	33	20	28	28
30	33	29	32	31	32	30	32	22	34	20	26	29
30	35	27	32	30	30	32	31	22	35	19	27	30
30	34	27	29	30	31	29	31	20	31	20	23	30
31	36	25	27	31	30	26	31	21	33	20	23	
29	35	26	26	31	30	27	28	23	33	19	22	
30	35	25	28	33	30	27	28	24	35	18	22	
32	34	25	29	33	28	27	27	24	33	20	26	
31	35	26	29	33	28	26	27	25	33	21	29	
31	33	31	28	34	28	26	28	29	31	23	27	
28	32	32	29	32	29	23	26	28	31	24	27	
30	34	32	28	37	30	21	28	30	31	23	27	
31	35	35	28	33	32	18	28	31	28	23	29	
31	34	33	27	38	30	19	28	30	28	24	28	
30	32	34	26	35	31	19	27	30	26	22	29	
30	33	34	25	33	31	17	29	30	24	21	30	
30	34	33	27	33	30	17	30	30	25	22	27	
31	34	35	27	36	31	17	29	31	26	24	28	
30	37	37	28	37	31	19	28	30	28	25	27	
28	34	36	28	39	31	19	29	30	26	25	29	
23	31	37	27	39	30	19	30	30	27	25	28	
25	31	34	26	38	30	22	31	28	27	24	28	
27	31	35	25	35	31	23	32	28	28	25	31	
25	32	36	24	33	30	26	31	29	30	26	27	
26	31	36	27	32	29	28	30	31	31	24	25	
25	32	38	27	33	24	29	31	30	31	29	28	
26	33	36	28	34	24	30	34	31	30	28	29	
27	31	37	29	31	24	31	33	30	30	28	29	
28	30	37	30	32	23	31	32	29	29	26	31	

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NUMBER OF SENSORS WITH SIGNAL LESS THAN NOISE AT GIVEN FREQUENCY INDEX

	1	51	101	151	201	251	301	351	401	451	501	551	601	651	701
1	59	0	0	1	4	4	7	16	35	38	52	37	33	30	27
2	59	0	0	1	5	4	7	18	32	38	50	38	35	33	27
3	59	0	0	1	5	5	7	19	33	40	52	39	35	31	28
4	59	0	0	1	4	5	6	20	32	39	55	43	33	33	27
5	59	0	0	2	5	5	6	20	34	41	55	42	29	34	29
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7	60	0	0	3	4	5	7	21	32	42	51	45	31	28	30
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9	60	0	0	1	5	4	8	30	32	42	53	44	33	30	29
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11	60	0	0	1	5	3	12	33	34	40	46	42	34	29	29
12	59	0	0	1	5	4	11	32	38	38	46	40	33	29	28
13	60	0	0	0	5	3	11	31	36	36	47	41	33	30	27
14	59	0	0	1	5	3	11	31	34	30	46	44	30	30	26
15	58	0	0	1	5	3	10	30	36	32	47	45	29	30	24
16	58	0	0	1	3	3	11	28	33	27	49	44	29	34	25
17	56	0	0	2	3	3	12	30	34	27	46	43	28	33	25
18	54	0	0	3	3	3	11	28	38	27	45	40	28	31	24
19	53	0	0	4	3	2	10	30	37	26	46	39	28	32	24
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21	48	0	0	4	1	3	8	30	38	25	48	37	27	32	23
22	42	0	0	5	1	3	8	32	37	27	47	40	30	30	20
23	38	0	0	5	1	5	10	33	36	28	48	41	33	29	18
24	32	0	0	5	1	4	9	33	34	30	49	42	30	31	17
25	29	0	0	5	1	3	11	32	33	31	49	39	28	28	16
26	30	1	0	5	2	2	12	33	32	35	46	38	30	26	15
27	24	1	0	4	2	2	11	34	33	36	50	38	32	25	15
28	18	2	0	4	0	2	10	39	31	36	52	40	32	26	17
29	12	2	0	4	0	2	8	41	32	40	54	41	32	27	18
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31	7	0	0	5	1	3	6	39	36	44	55	40	32	22	16
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46	0	2	1	2	3	4	14	41	36	57	41	34	32	22	13
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